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PROJECT

HAZEL

RIGID CONSTRUCTION VEHICLES

SUMMARY REPORT

Report No. ZP-267

May 1959

CONVAIR

A DIVISION OF GENERAL DYNAMICS CORPORATION

SAN DIEGO

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BACKGROUND

CONVAIR SAN DIEGO has conducted studies, under the direction of the BuAer, of low detectibility, high altitude, high speed, manned reconnaissance systems. Many approaches were considered, such as:

1. Boost Glide System

   (Average Altitude 170,000 ft.; maximum velocity 15,000 ft/sec.; 3200 N Mi Range).

2. Boost Cruise Systems

   A. Rocket Cruise Power (Average Altitude 150,000 ft.; M-8.0; 3200 N Mi Range)

   B. Ramjet Cruise Power
      (1) Plastic inflatable vehicle (Altitude 150,000 ft.; M3; 3200 N Mi Range)
         a) Pentaborane-fueled
         b) Hydrogen-fueled
      (2) Typical Rigid Vehicles (All M3.0; Range 4000 N Mi)
         a) Pentaborane-fueled (Average Altitude 105,000 ft.)
         b) Hydrogen-fueled (Average Altitude 104,000 ft.)
         c) JP-4 fuel (Average Altitude 92,000 ft.)

Various methods of launching the above vehicles to cruise altitude and speed were studied, such as:

1. Solid Rocket boost from the ground.
2. Liquid Rocket boost from the ground.
3. Solid Rocket boost from carrier aircraft.
4. Liquid Rocket boost from carrier aircraft.
5. Jet engine pod booster, from the ground.

In addition to the configuration and performance of the systems studied above, Convair San Diego has performed calculations to determine I.R. and radar detectibility and tests to determine the radar cross section of the most promising vehicles.

FOREWORD

This report describes the all rigid, low altitude (approx. 100,000 ft.) configurations of the Project "Hazel" studies performed by the Convair San Diego Division of the General Dynamics Corporation. This report represents Convair's fulfillment of Item II of the publication obligation specified in Contract NOas-58-812 (SS-100) Amendment #3, issued 23 Dec. 1958 by the Bureau of Aeronautics.

GROUND RULES

The starting ground rules for this study were as indicated on this chart. The altitude was lowered from the previous studies (see Background) to allow for smaller vehicles and possibility of utilizing JP fuel. The speed has been held at M3.0, however, the range was increased from 3200 N Mi. to 4000 N Mi.

One of the most important requirement changes from the previous studies was the structure change from "Plastic Inflatable" to "typical Rigid."

All the vehicles considered in this study are boosted to cruise altitude and speed. These various boost methods will be discussed later.

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GROUND RULES

ALTITUDE	APPROX.	100,000	FT.
SPEED	MACH	3.0	
RANGE		4000	N.MI.
CREW		1	
PAYLOAD		500	POUNDS
CONSTRUCTION			
AIRFRAME	TYPICAL	RIGID	METAL
ENGINES	TYPICAL	RIGID	METAL

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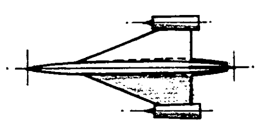
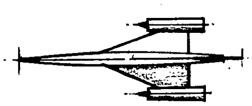
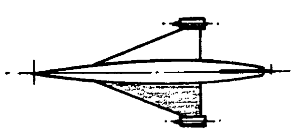
SUMMARY

Within the ground rules as previously stated, three types of vehicles were designed; Pentaborane fueled, JP fueled, and Liquid Hydrogen fueled. The results are shown on this chart. All gross weights are at start of cruise.

As would be expected, the Hydrogen vehicle is the lightest, resulting from the high BTU content per pound of fuel. The large body results from the low density of Hydrogen.

The Pentaborane fueled vehicle is the next lightest, with JP the heaviest, however, there's only approximately 3000 pound difference from lightest to heaviest. Off-hand this seems a cheap price to pay for the reduced hazards and complexity of the JP fueled vehicle.

SUMMARY
(HIGH PERFORMANCE AIRCRAFT)

		GROSS WEIGHT (LBS.)	WING AREA (SQ.FT.)	CRUISE ALTITUDE AVERAGE -(FT)
P.B.		9,700	500	105,600
JP-4		12,190	300	92,200
HYD.		9,100	500	104,350

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JP-4 RAMJET

This chart shows the details of the JP-4 fueled vehicle. This is a straight forward, state of the art, vehicle throughout, typical rigid metal construction on both the airframe and ramjet engine.

The airframe weight is predicated on titanium material, however this is dependent on further study and test work in the determination of laminar versus turbulent flow, at the cruise altitude and speed of this vehicle. Unfortunately this vehicle cruises in the transition region between laminar and turbulent flow, with the results of not being able to determine with sufficient degree of certainty the design temperature. Convair San Diego has been conservative in assuming turbulent flow, in which case the temperature 10 ft. from leading edge of wing is 545°F; if, however, this should be in the region of laminar flow the same location would be 305°F. If, this region of uncertainty, does happen to be laminar (305°F) then aluminum could be used as airframe structure.

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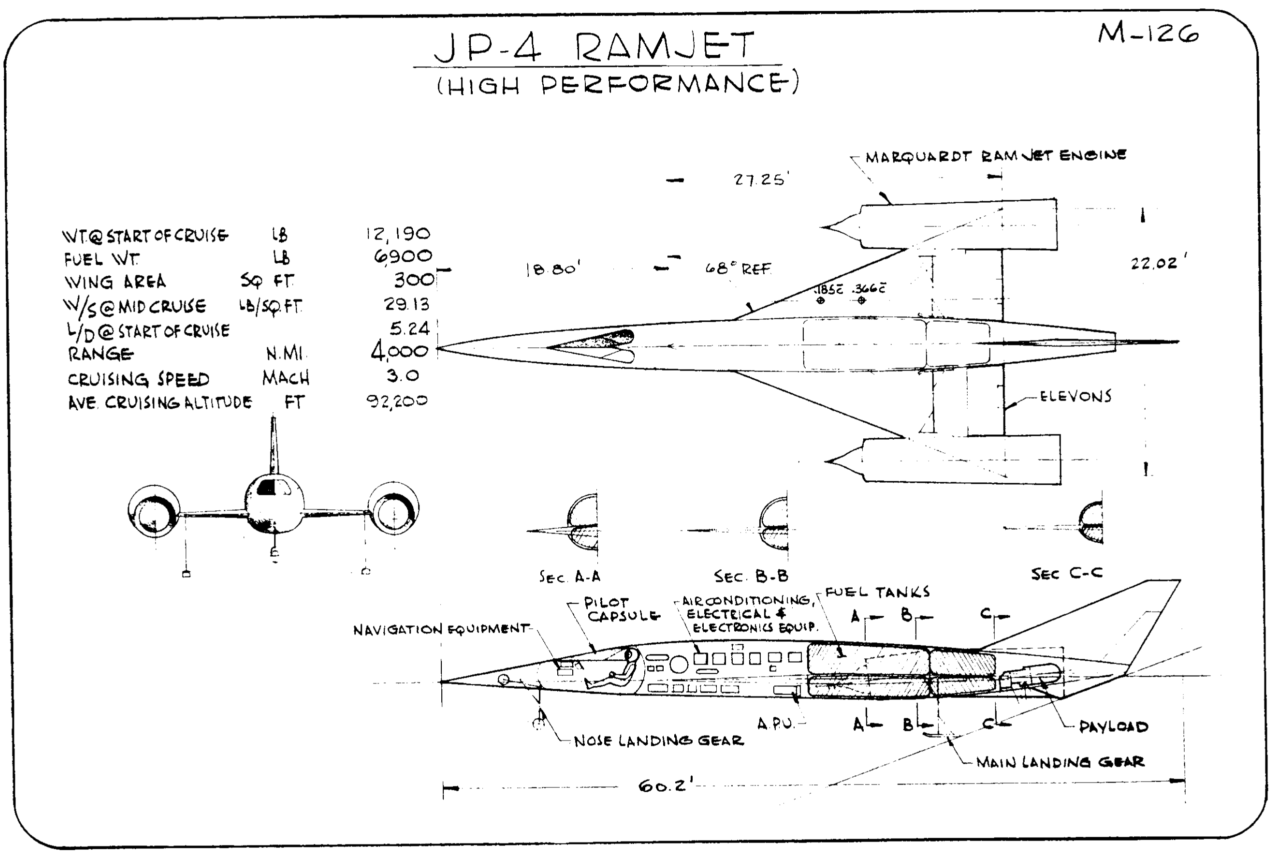

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MISSION PROFILE

This particular mission is for the Pentaborane fueled vehicle, however it is typical for the Pentaborane, Hydrogen, and JP fueled type of vehicle, with the exception of cruise altitude.

The JP vehicle, shown on the last chart, will cruise at an average altitude of 92,200 ft. instead of the 105,000 ft. shown for the P.B. vehicle on the chart.

This mission profile shows the launch from a carrier aircraft (such as B-52) with rocket boost to cruise altitude and speed. Other types of boost will be discussed later.

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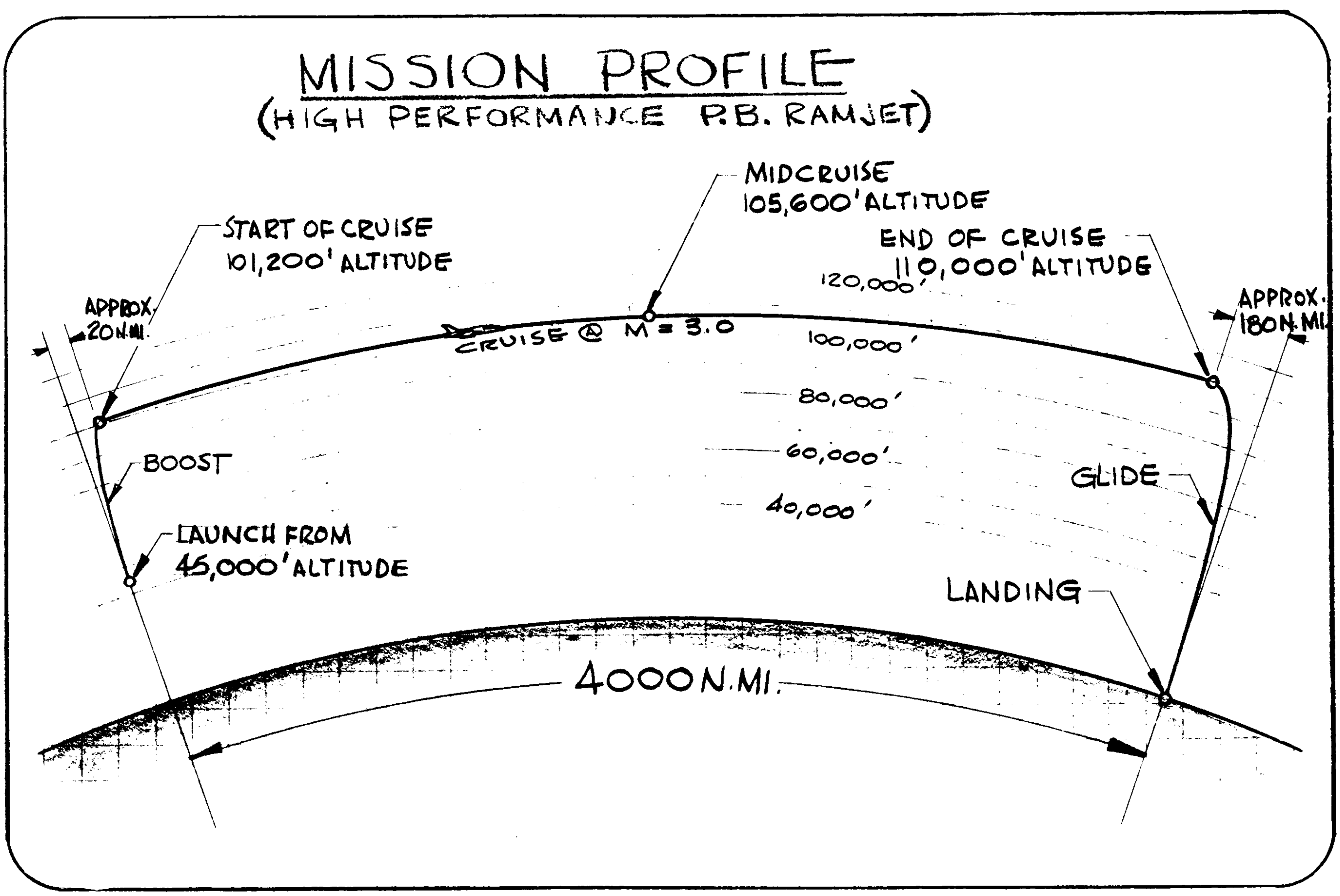

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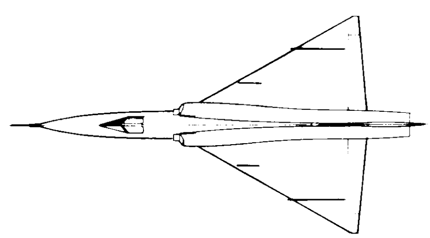
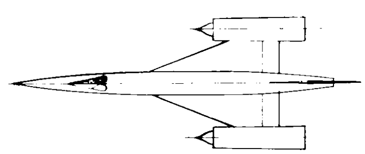
COMPARISON

F-106A



G.W. = 35,000 LB.

JP-4 VERSION



G.W. (START CRUISE) = 12,190 LB.
LAUNCH WT. (GROUND) = 32,000 LB.
LAUNCH WT. (B-52) = 18,000 LB.

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TURBOJET GROUND LAUNCH

After considerable study of various launching methods, it was concluded that one of the most promising was a take-off and fly-up launch using a jettisonable turbojet booster pod. Such a booster pod might utilize a J-58 engine and would incorporate fuel tanks and a landing gear adequate to both take-off and land the vehicle booster combination. The booster would probably only be jettisoned on actual military objective flights, and two systems should be considered; recoverable booster pod (parachute), and expendable booster pod.

There was not sufficient funds to make a complete study of this type of boost, however this chart indicates a very preliminary check into the possible performance of such a system. It does indicate that there is a good possibility of accomplishing such a boost system.

It does indicate that a 10,000 pound vehicle could be boosted to approximately 90,000 ft. at M2.92, after a normal take-off and fly-up. This altitude and speed is sufficient for ramjet lite-off for cruise.

Convair believes that this type of launch combined with the JP fueled vehicle, would produce the most simple, inexpensive, type of reconnaissance system.

It must be admitted, that further study is required before the practicability of such a launch system is with out question.

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TURBOJET GROUND LAUNCH
(J-58)

PRELIMINARY ONLY

T.O. WEIGHT = 25,000 LB.

ENGINE WEIGHT = 5,500 LB.

MISCELL. WEIGHT = 1,500 LB.
(TANKS, ATTACH., LANDING GEAR, ETC.)

FUEL WEIGHT = 8,000 LB.

BOOSTER WEIGHT = 15,000 LB.

VEHICLE CRUISE WEIGHT = 10,000 LB.

$\boxed{90{,}000 \text{ FT. @ } M = 2.92}$

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RADAR CROSS SECTION

This chart indicates the status and predictions of the radar cross sections at 70 MC of the type of vehicle we have been discussing.

It is estimated that the radar cross section of the three vehicles (Pentaborane, Hydrogen, and JP fueled) before any attempt has been made to reduce this, with known radar reduction cross section techniques, would be as shown; <40 square meters for nose and tail views, and <200 square meters for broadside view. This has been borne out by vehicle model test, since this chart was produced.

Previous radar reduction tests have indicated very strongly the possibility of reducing these to 8, 8 and 25 as shown in chart.

As the chart indicates, it is considered possible to further reduce, with more exotic methods, the radar cross section to possibly 3, 3 and 10 square meters. This reduction does require additional model testing, however, sufficient background on flat plate testing does exist to indicate the possibilities of cross section reductions as discussed above.

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RADAR CROSS SECTION

	AS IS	POSSIBLE REDUCTION BASED ON PAST TEST	FURTHER OPTIMIZING
NOSE	$< 40 m^2$	$8 m^2$	$3 m^2$
TAIL	$< 40 m^2$	$8 m^2$	$3 m^2$
BROADSIDE	$< 200 m^2$	$25 m^2$	$10 m^2$

ZP 267-7

PENTABORANE RAMJET

This chart indicates the details of the Pentaborane fueled vehicle, note the 9700 pounds gross weight versus 12,190 pounds for the JP-4 vehicle, also the higher cruise altitude; 105,000 ft. versus 92,200 ft. The cost, hazards, and complexity of the exotic Pentaborane fuel seems a severe penality for the small saving in gross weight plus higher cruise altitude.

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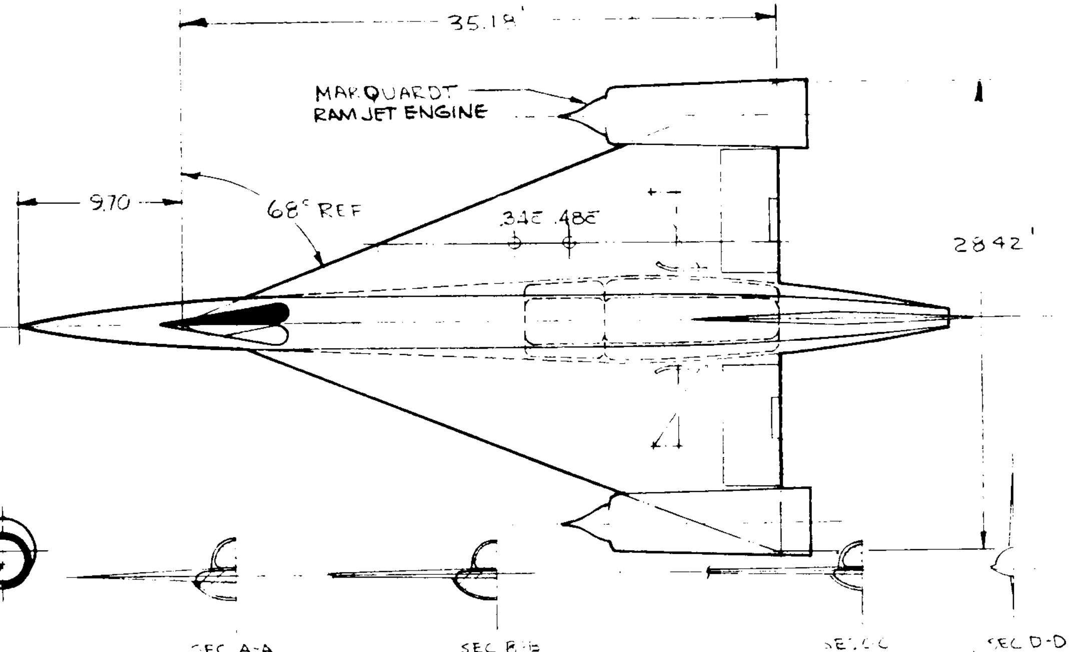
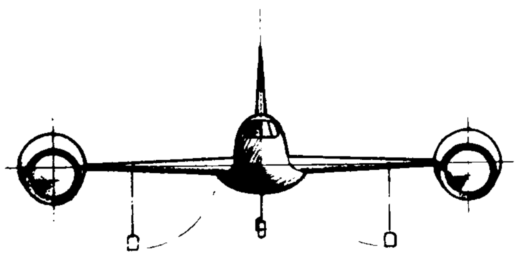
PENTABORANE RAMJET

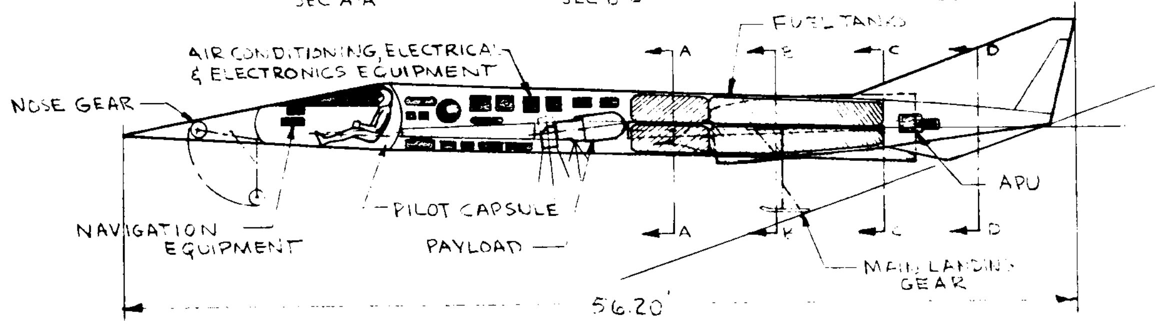
(HIGH PERFORMANCE)

M-124 A

WT @ START OF CRUISE	LB	9,700
FUEL WT.	LB	4,030
WING AREA	SQFT	500
W/S @ MID CRUISE	LB/SQFT	15.37
L/D @ START OF CRUISE		5.7
RANGE	N. MI	4000
CRUISING SPEED	MACH	3.0
AVE CRUISING ALTITUDE	FT.	105,600







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HYDROGEN RAMJET

This chart shows the details of the Liquid Hydrogen fueled vehicle. Like the pentaborane vehicle on the last chart, this Hydrogen vehicle hardly seems worth the added complexity, hazard, and cost to attain the lower gross weight and high cruise altitude.

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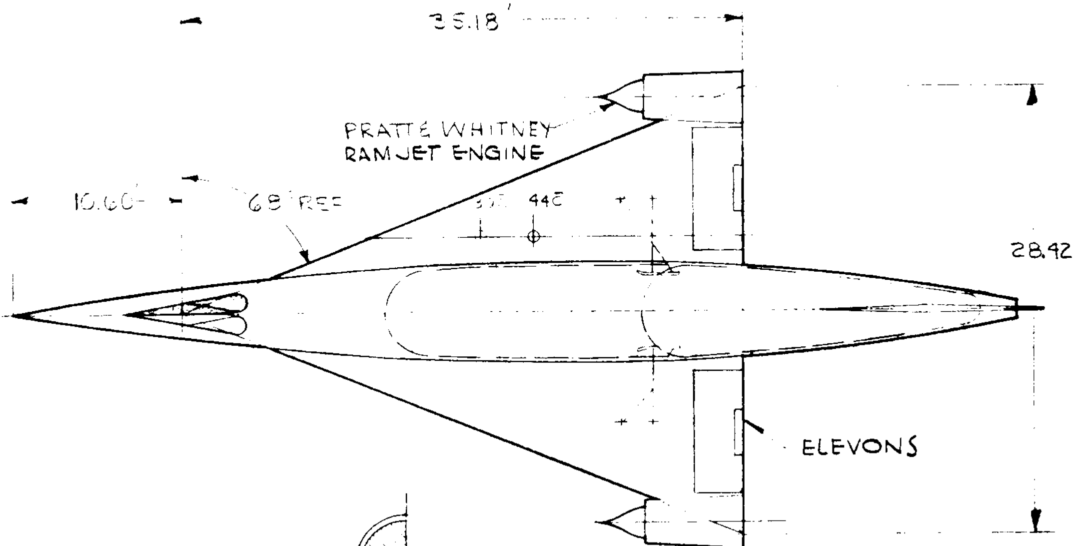
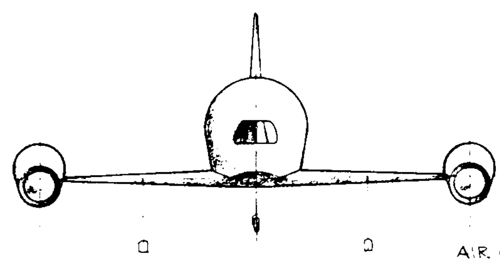
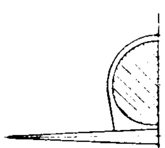
P-124C

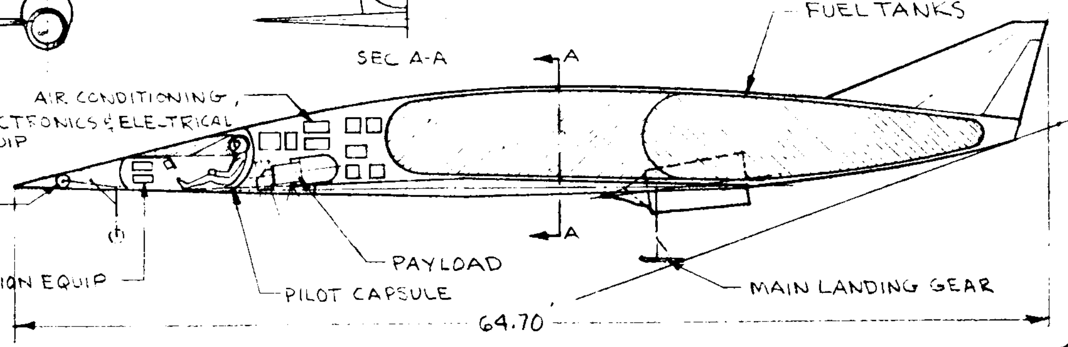
HYDROGEN RAMJET
(HIGH PERFORMANCE)

WT @ START OF CRUISE	LB	9100
FUEL WT	LB	2920
WING AREA	SQFT	500
W/S @ MID CRUISE	LB/SQFT	15.3
L/D @ START OF CRUISE		5.19
RANGE	N MI	4000
CRUISING SPEED	MACH	3.0
AVE CRUISING ALTITUDE	FT	104,350









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JP-4 VERSION OF PENTABORANE AIRCRAFT

This vehicle was designed as a possible step in the development program of the Pentaborane vehicle. This would be the exact Pentaborane configuration discussed earlier, but with the pentaborane ramjets removed and replaced with JP-4 fueled ramjets with necessary fuel system. The pentaborane tank would then be fueled with JP-4, resulting in an increase in gross weight from 9700 pounds to 10,530 pounds as shown.

In order to reduce cruise altitude within burning limit of JP-4, this configuration would have to fly at a lower angle of attack, resulting in reduced L/D. This, coupled with S.F.C. of JP-4, reduces range from 4000 to 2960 as indicated on chart.

This approach is presented, only as an interesting possibility.

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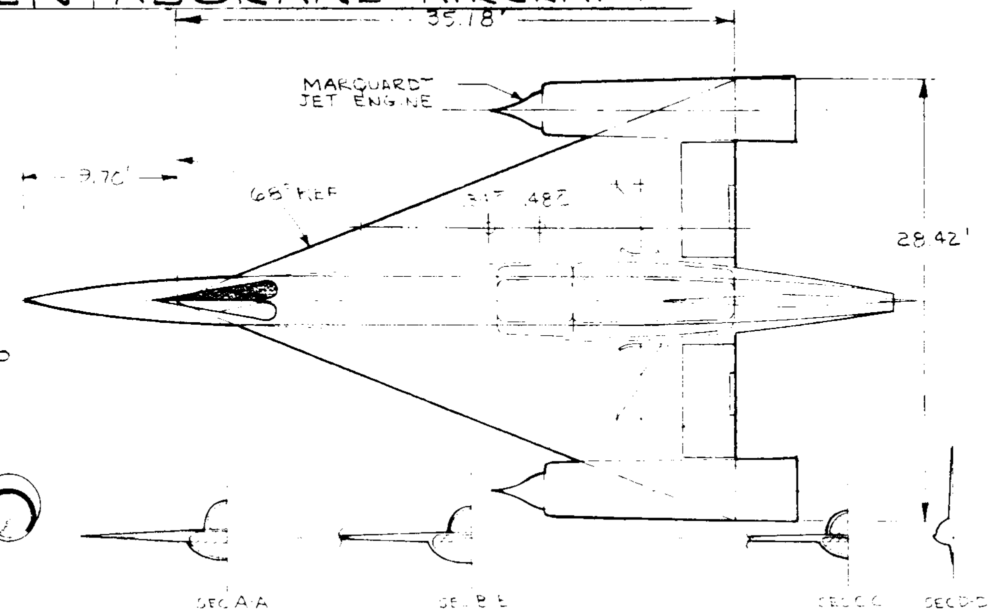
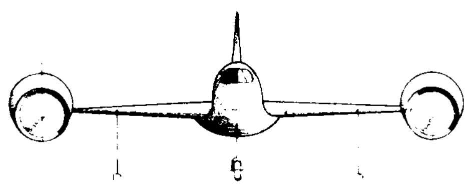
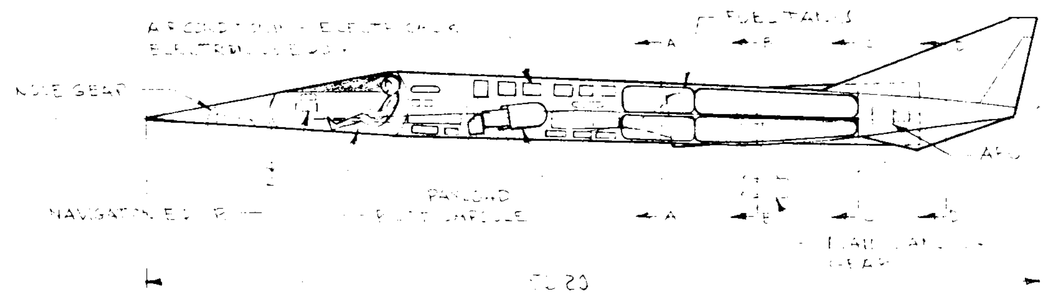
M-124B

JP-4 VERSION OF PENTABORANE AIRCRAFT

WT @ START OF CRUISE	LB	10,530
FUEL WT	LB	4,970
WING AREA	SQ FT	500
W/S @ MID CRUISE	LB/SQ FT	16.09
L/D @ START OF CRUISE		5.15
RANGE	N. MI	2960
CRUISING SPEED	MACH	[illegible]
AVE CRUISING ALTITUDE	FT	95,400







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TRAINING VERSION OF PENTABORANE AIRCRAFT

This chart shows an Altitude-Mach No. envelope, and typical type of mission, that can be flown with a so-called "Training Version" of the basic pentaborane vehicle. The modification would consist of replacing the pentaborane ramjets with J-85 turbojets and utilizing JP-4 fuel to gross weight of 10,000 pounds.

This would provide the possibility of normal take-offs and landings for training purposes--not requiring the expensive types of booster systems.

Again, this approach is presented, only as an interesting possibility, for inexpensive training and early phase development.

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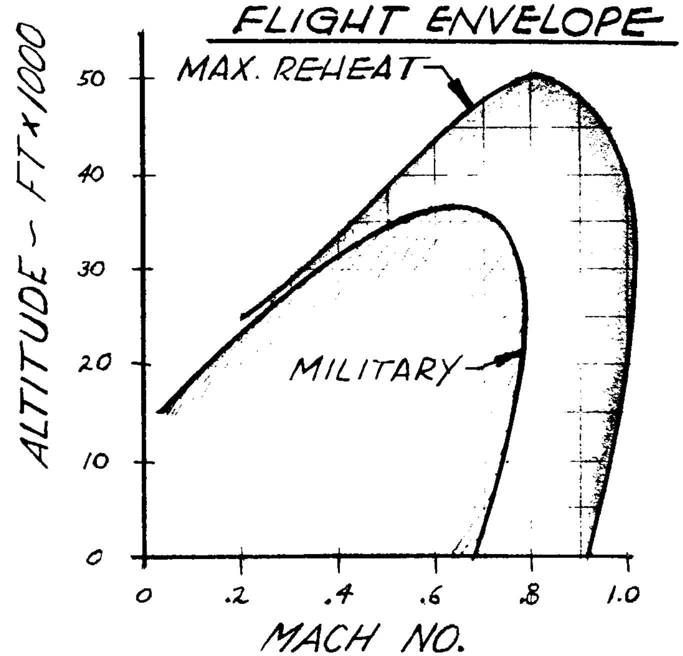
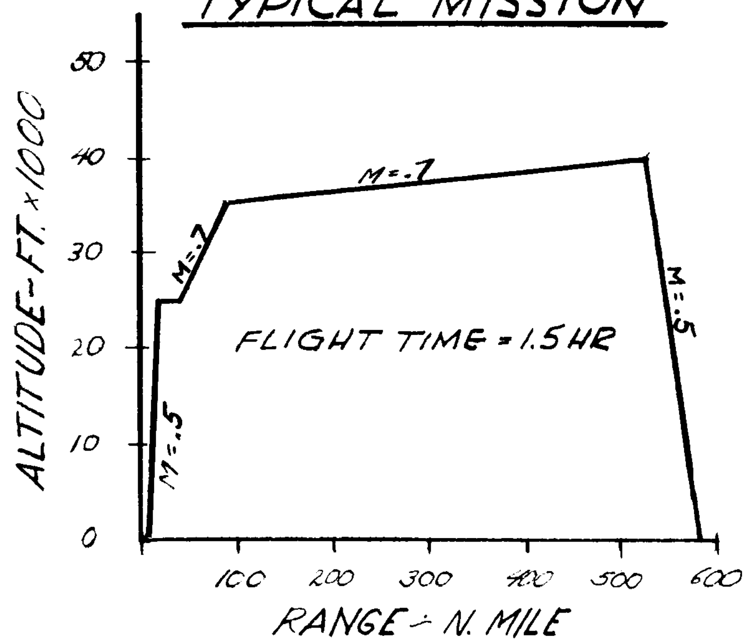
TRAINING VERSION OF PENTABORANE AIRCRAFT

(2 J-85 TURBOJETS REPLACING 2 RAMJETS)
G.W. = 10,000 LBS

FLIGHT ENVELOPE



TYPICAL MISSION



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PENTABORANE RAMJET

This configuration was designed to determine the performance penalties resulting from a vehicle designed for minimum radar cross section. The ramjets were located in the shadow of the wing to minimize ramjet reflectivity. This resulted in a 60° wing sweep in place of the 68° and wing tip elevons.

As shown these performance penalties, resulted in a gross weight increase to 11,050 pounds from 9700 pounds, to perform same mission of 4000 N Mi.

Model tests have been conducted to determine the degree of success attained in reducing cross section with this configuration. These tests indicate very little decrease in detectability considering the performance penalties.

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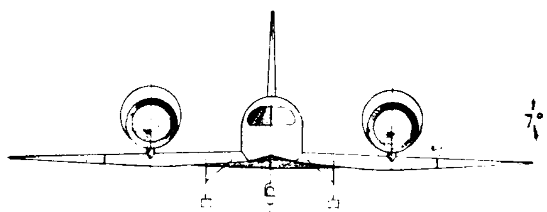
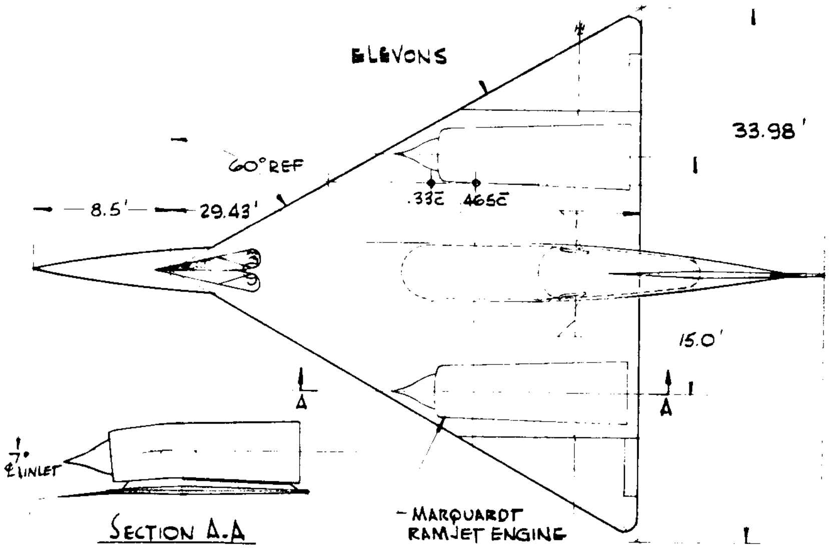
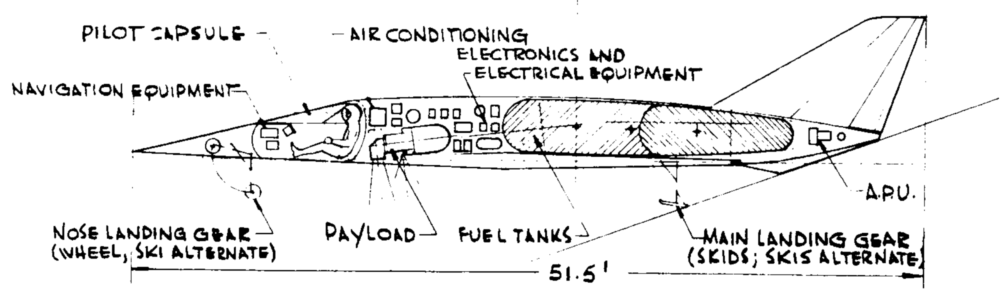
PENTABORANE RAMJET
(MINIMUM RADAR CROSS SECTION)

M-125

WT. @ START OF CRUISE	LB	11,050
FUEL WT.	LB	5,100
WING AREA	SQ. FT	500
W/S @ MIDCRUISE	LB/SQ. FT.	17.0
L/D @ START OF CRUISE		5.05
RANGE	N MI.	4,000
CRUISING SPEED	MACH	3.0
AVE. CRUISING ALTITUDE	FT.	102,300







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SUMMARY

This chart summarizes all vehicles studied. On the left are the three basic configurations; Pentaborane, JP-4 and Hydrogen. On the right are the three versions of a typical pentaborane vehicle.

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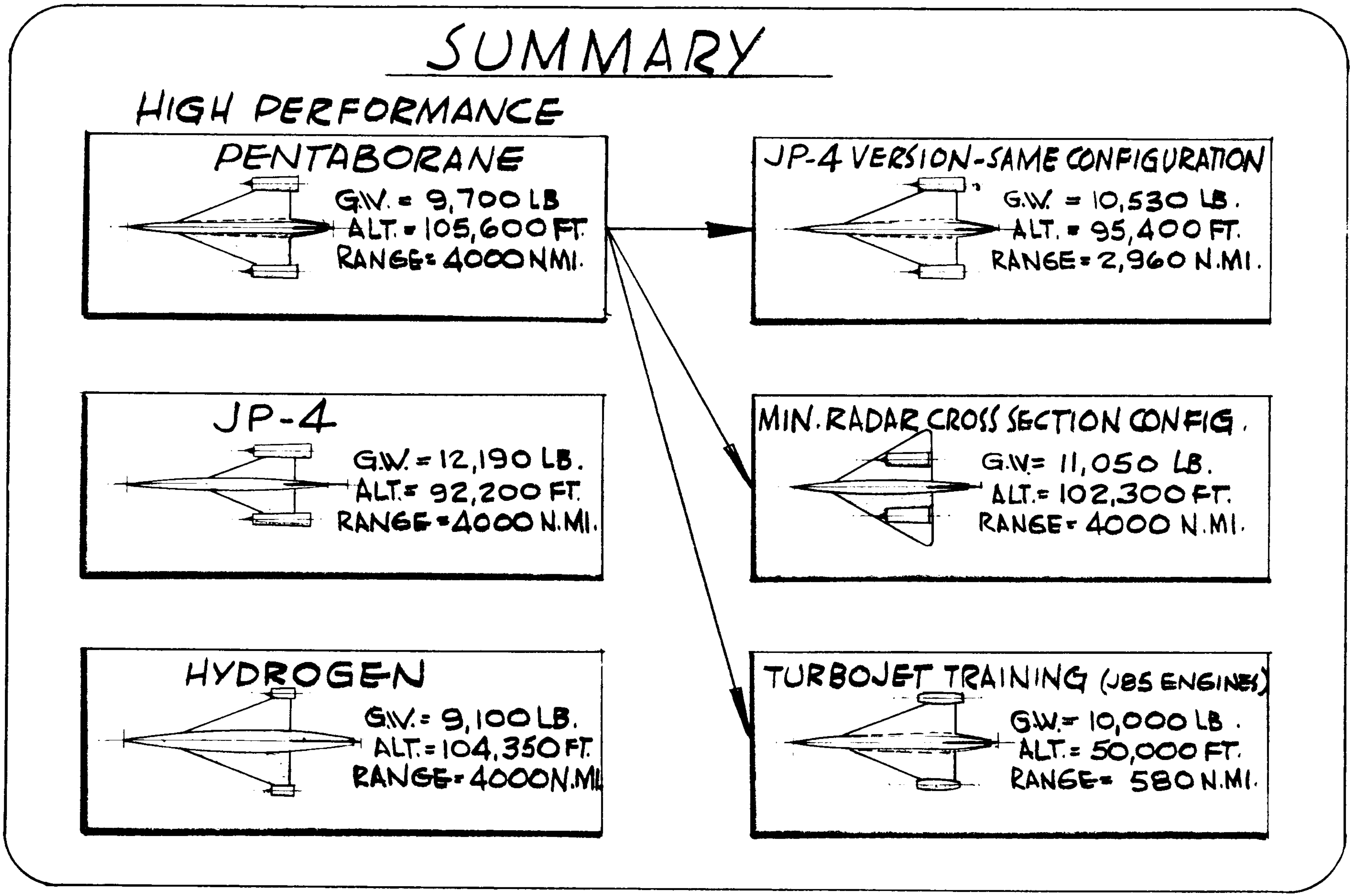

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LAUNCH GROUND RULES

It was decided to conduct the launch studies on a 10,000 pound gross weight vehicle as a typical weight (actual weights varied from 9100 to 12,190 pounds). Funds did not permit launch studies of all three vehicle weights.

This group of launch studies was to be confined to ground and B-52 air launch only. It was also decided that the pentaborane vehicle would be used in the launch configuration drawings.

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LAUNCH

GROUND RULES:

AIRCRAFT G.W. 10,000# ~ ARBITRARY

CONSIDER ONLY $\left\{\begin{array}{l}\text{GROUND LAUNCH}\\\text{B-52 AIR LAUNCH}\end{array}\right.$

AIRCRAFT CONFIG. ~ P.B. HIGH PERFORMANCE

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GROUND LAUNCH (SOLID FUEL ROCKET)

This chart shows the results of ground launch-straight up—with three stage solid rockets. The objections to the type of launch are; stability requirements at launch (first stage firing), the necessity for light-off of three stages, and the pilot hazards in initial stage of launch.

At present, this is not a recommended launch system.

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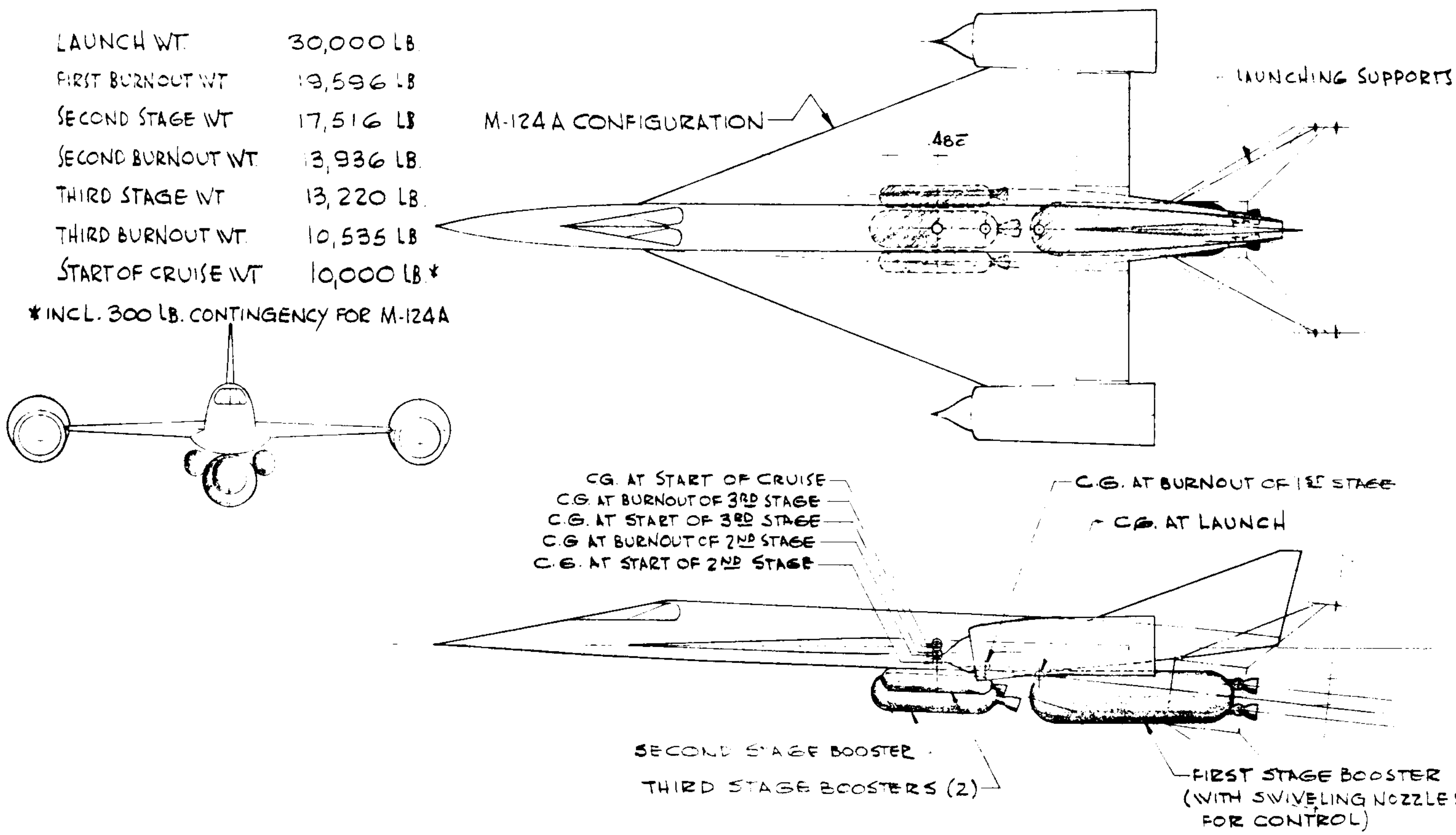
GROUND LAUNCH
(SOLID FUEL ROCKETS)

LAUNCH WT.	30,000 LB.
FIRST BURNOUT WT	19,596 LB
SECOND STAGE WT	17,516 LB
SECOND BURNOUT WT.	13,936 LB.
THIRD STAGE WT	13,220 LB.
THIRD BURNOUT WT.	10,535 LB
START OF CRUISE WT	10,000 LB.*

*INCL. 300 LB. CONTINGENCY FOR M-124A



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GROUND LAUNCH (LIQUID FUEL ROCKET)

This launch system is similar to the solid boost on the last chart, except for the added advantage of 1-1/2 stage in place of 3. All three rocket engines are started at launch, and at staging the two outer engines plus tanks are jettisoned, leaving the still burning center engine. No light-off in flight.

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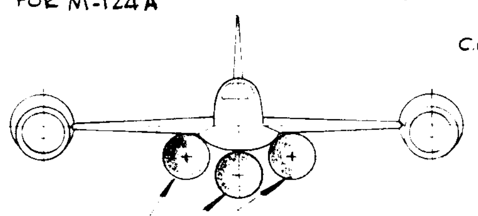
GROUND LAUNCH

(LIQUID FUEL ROCKETS)

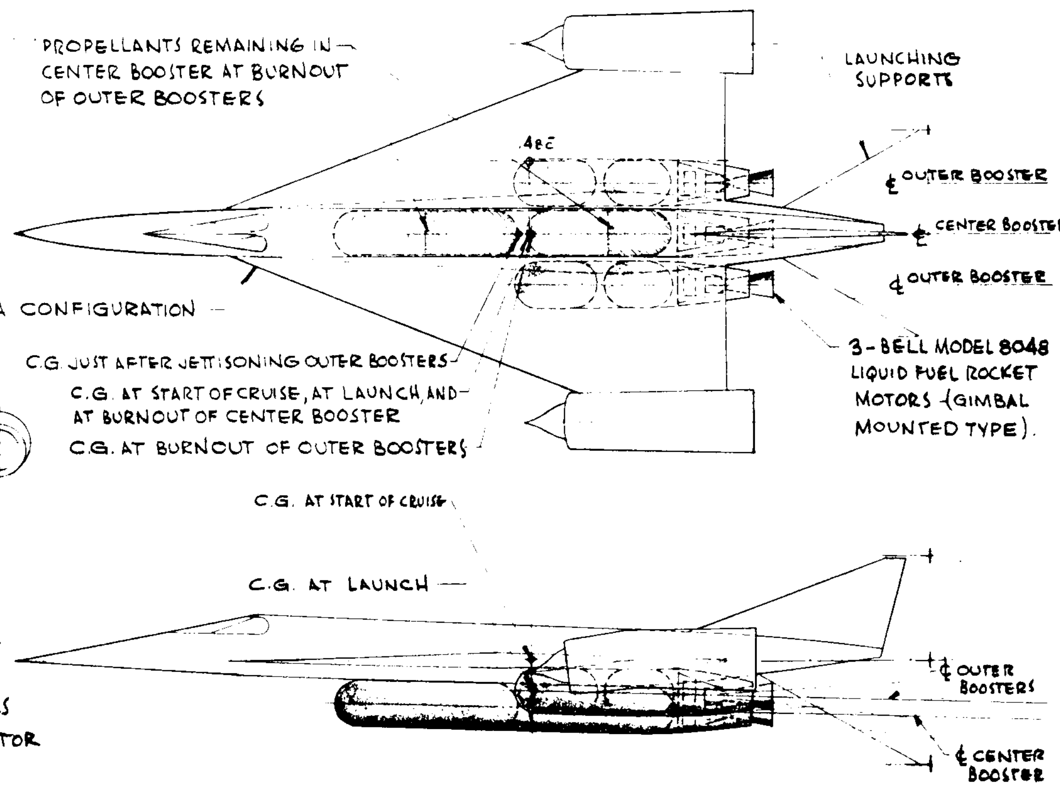
FUEL	U.D.M.H.
OXIDIZER	I.R.F.N.A.

LAUNCH WT	32,000 LB
FIRST BURNOUT WT.	19,930 LB
SECOND STAGE WT	17,516 LB
SECOND BURNOUT WT.	11,251 LB.
START OF CRUISE WT	10,000 LB *

* INCL. 300 LB CONTINGENCY FOR M-124A



BOOSTER IS $1\frac{1}{2}$ STAGE TYPE. ALL THREE MOTORS OPERATE FOR INITIAL STAGE, THEN OUTER TWO MOTORS & TANKS ARE DROPPED CENTER MOTOR CONTINUES.



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AIR LAUNCH (WITH B-52 CARRIER)

This drawing indicates the capability of the B-52 to easily handle one or two of the vehicles. There is, of course, many advantages to this system; extension of range, two vehicles would give double reliability, reduced pilot hazard, and a carrier aircraft such as the B-52 would provide an important platform from which to develop the vehicle.

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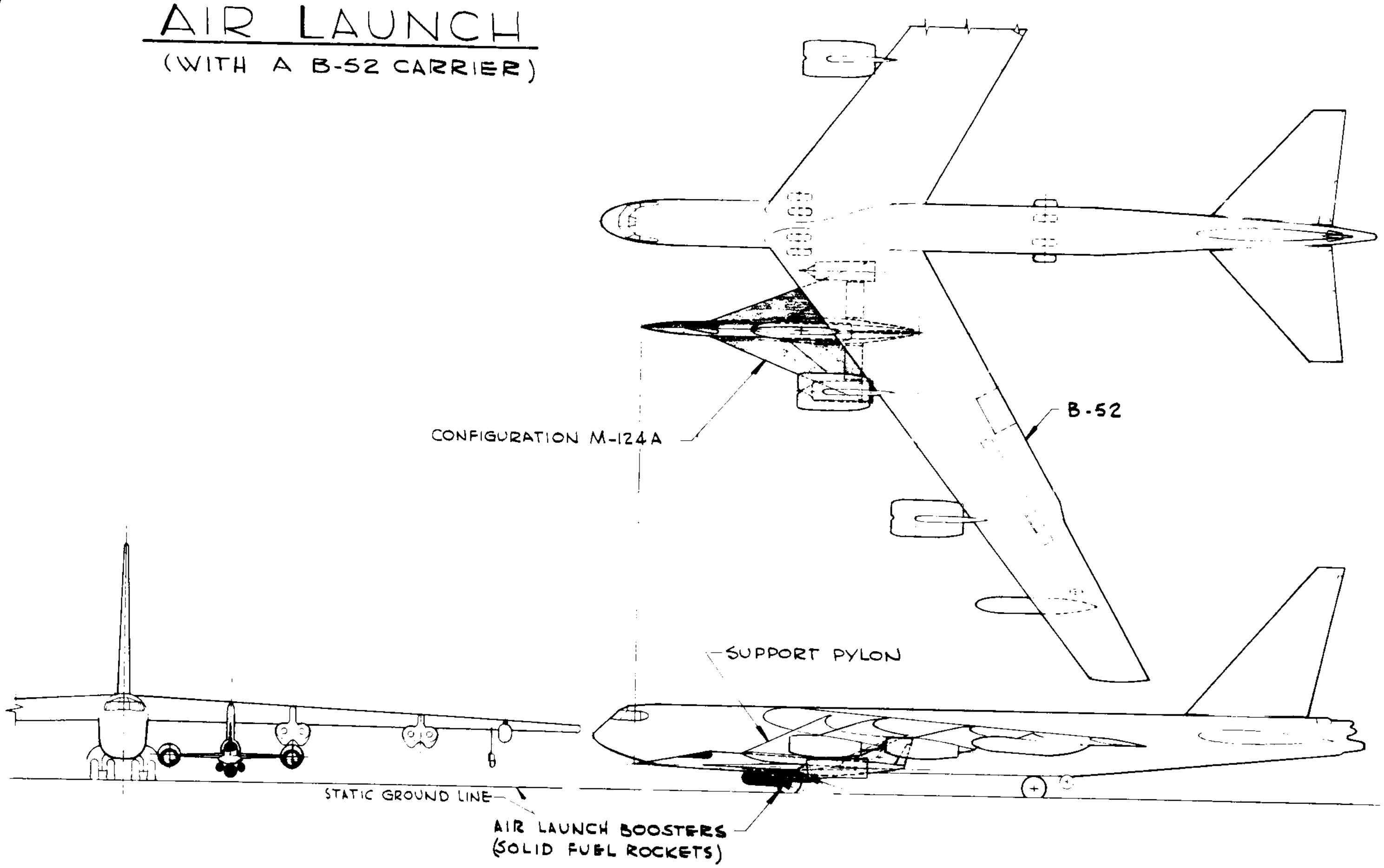
AIR LAUNCH
(WITH A B-52 CARRIER)



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AIR LAUNCH

This chart indicates a two stage solid rocket booster system that could be used to attain cruise altitude and speed from B-52 launch. It utilizes the second and third stage of the three stage boost from ground discussed previously. This gives a weight at launch of 17,516 pounds.

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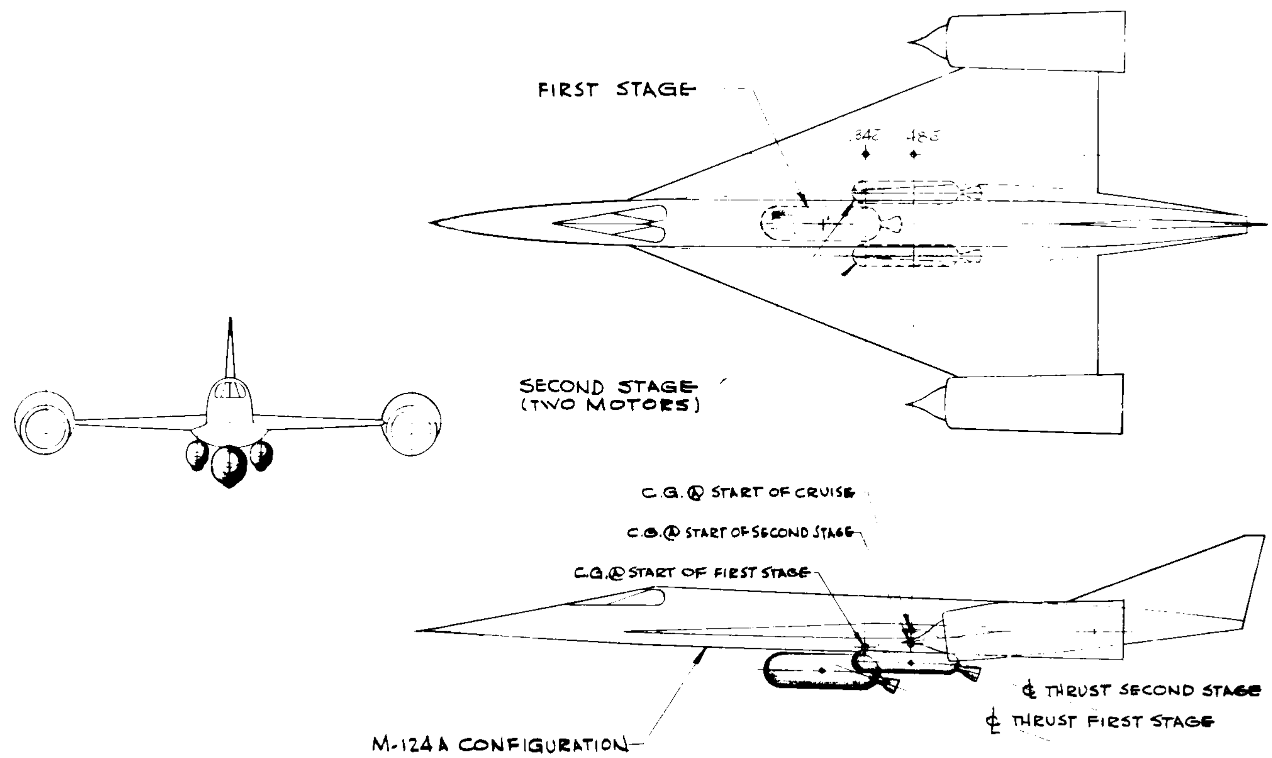
AIR LAUNCH

(CONFIGURATION M-124A WITH SOLID FUEL ROCKETS)



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SEA BASING

This chart depicts two methods of sea basing the JP-4 fueled vehicle using solid rocket boosters. Liquid rocket boosters could be utilized in the same manner. It is interesting to note that a vehicle of such small size is readily adaptable to launch from a common transport ship.

For reduced vulnerability, a folded wing version can be adapted to some form of submarine tube as indicated in lower portion of the chart.

It must be admitted that further detailed study is certainly in order to determine the details of such launches, however, present studies indicate their feasibility.

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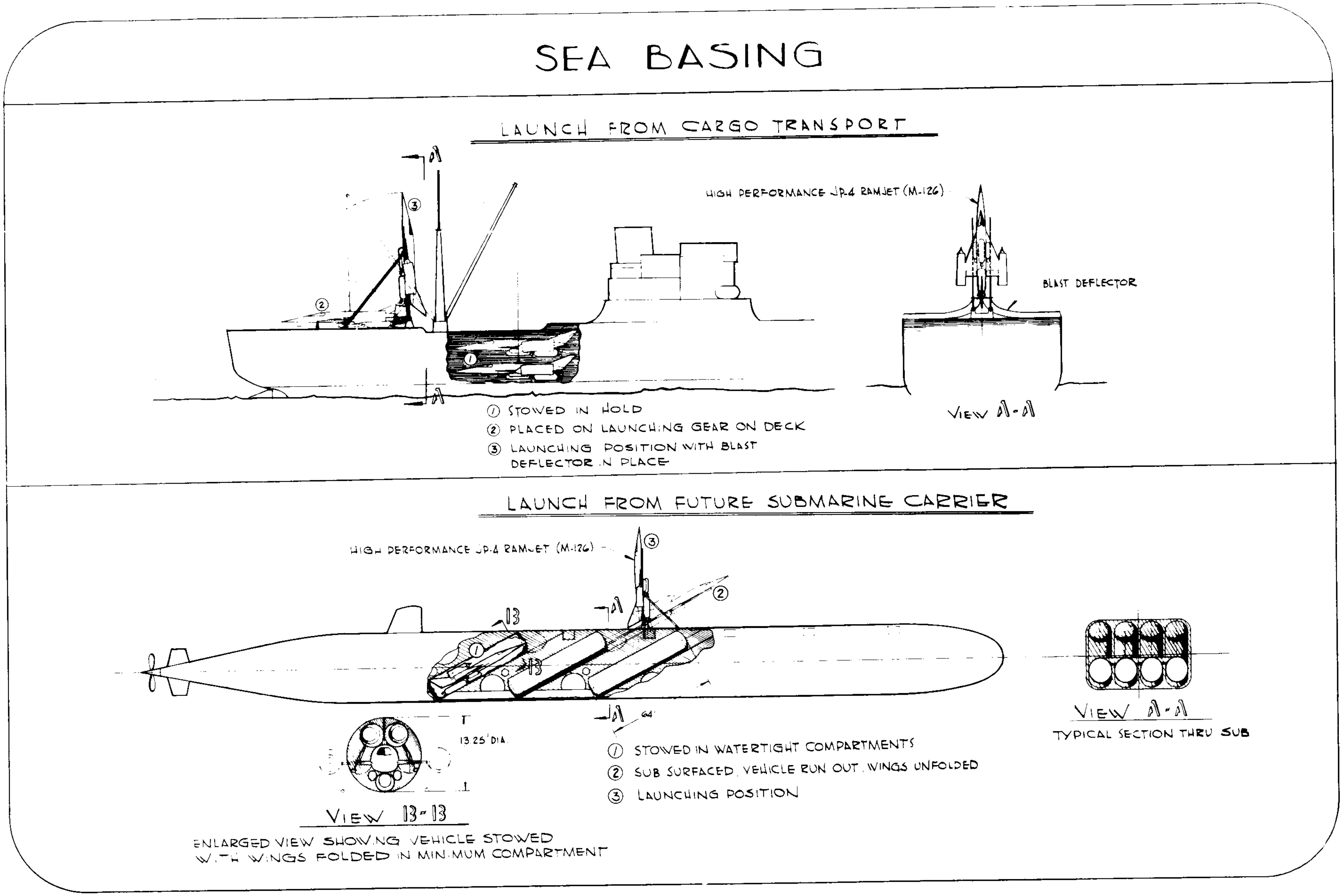

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LAUNCH SUMMARY

This chart is a summary of all launches considered. The "Zero G" Ground Launch Study was terminated before completion, because it did not seem to offer any advantage over the "straight-up" launch.

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LAUNCH SUMMARY

(10,000 LB. CRUISE VEHICLE)

GROUND

	T.O. WT. (LB.)	TYPE T.O.	ULT. ALT. (FT.)	STAGES
SOLID	30,000	STRAIGHT UP	100,000	3
LIQUID	32,000	STRAIGHT UP	100,000	1½
LIQUID	?	ZERO "G" LAUNCH (UNDER STUDY)	100,000	1?
TURBOJET (J58)	25,000	NORMAL T.O. (FLY UP)	90,000	1 + SMALL R.J. HELP?

AIR (B-52; SUBSONIC 55,000 FT.)

SOLID	17,500	FLY UP	100,000	2
TURBOJET (J58)	?	FLY UP	?	1 + SMALL R.J. HELP?

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WHICH SYSTEM?

CONVAIR SAN DIEGO's recommendation at this stage of study would be as indicated on this chart. It must be admitted that further studies are in order to investigate other launching techniques, such as ramjet climbout to cruise altitude and speed from a supersonic aircraft such as a B-58. A further study of the J-58 turbojet pod is in order.

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WHICH SYSTEM?

- JP-4 CRUISE VEHICLE
    - MINIMIZE FUEL PROBLEMS
        - LOGISTICS, HANDLING, HAZARDS
    - SMALL SIZE
        - MINIMUM RADAR AND I.R.
    - LOW WEIGHT
    - STATE OF ART CONSTRUCTION
    - ENGINE – STATE OF ART
        - SMALL SIZE (EXISTING FACILITIES)
        - SIMPLE (NO VARIABLE GEOMETRY)
        - CONSTRUCTION (SIMPLE RIGID METAL)
- BOOST
    - J58 POD FLY-UP (REQUIRES FURTHER STUDY)
    - B-52 LAUNCH IF J58 POD FLY-UP NOT ATTRACTIVE AFTER FURTHER STUDY

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CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO

REPORT ZP-266
DATE March 1959
MODEL

SECRET

TITLE

PROJECT HAZEL

AIRCRAFT DESIGN

CONTINUED STUDIES

Contract No. NOa(s) 58-812 (SS-100) Amendment 3

Report ZP-266

March 1959

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NO. OF PAGES 44
NO. OF Figures 18
No. of Tables 3

REVISIONS

NO.	DATE	BY	CHANGE	PAGES AFFECTED

FORM 1612 A-4

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FOREWORD

This report describes the Inflatable and Rigid High Altitude (approximately 132,000 ft.) configurations of the Project "Hazel" studies performed by the Convair San Diego Division of the General Dynamics Corporation. This report represents Convair's fulfillment of Item I of the publication obligation specified in Contract NOas-58-812 (SS-100), Amendment #3, issued 23 December 1958 by the Bureau of Aeronautics.

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SYNOPSIS

This report is a continuation of the "High Altitude" Hazel studies reported in ZP-252 "Project Hazel Summary", ZP-253 "Aircraft Design", ZA-282 "Aerodynamics", and ZJ-026 "Propulsion, Structure Heating and Pressurization". Three main objectives are covered: 1. Launch Study, 2. All Metal Airframe Design and 3. Test Model Wing Design.

The launch study examines the launch requirements to allow design for only the cruise or post cruise maneuver airloads. The launching method chosen utilizes an airplane such as a B-36 or B-52 for the initial boost and a two stage rocket for the secondary boost.

The all metal airframe assumes an all magnesium construction of integrally stiffened panels and multi spar wing. The metal airframe is slightly larger and heavier than the non-metallic airframe, but would require less of a development program and would give improved maintenance.

The test model wing design is based on all metal construction and is designed to be comparable with a similar non-metallic wing being built by Goodyear Aircraft Corporation.

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FIGURES (CONT'D)

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INTRODUCTION

This report is a continuation of the "High Altitude" Hazel studies reported in ZP-252 "Project Hazel Summary", ZP-253 "Aircraft Design" ZA-282 "Aerodynamics", and ZJ-026 "Propulsion, Structure Heating and Pressurization", October 1958 by Convair, San Diego, A Division of General Dynamics under the same contract, Amendment #3, 23 December 1958, NOas 58-812 (SS-100) of 14 August 1958. It consists of three general areas of study, I. Launch Study, II. All Metal Airframe Design, and III. Test Model Wing. Section I describes the launch method required to put the basic MC-10 vehicle at its design start of cruise position and velocity without exceeding structural limitations. Section II describes design of an extremely light all-metal vehicle to accomplish the same mission as the MC-10 configuration of ZP-253. Section III gives the design details of an all-metal test model wing to compare with the pressure stabilized non-metallic test model wing, being built by Goodyear Aircraft Corporation. Appendix A is an evaluation of a phase of the launch method proposed.

Report ZP-253 established the basic mission and design requirements for the "Hazel" vehicle. The high altitude cruise demanded extremely light wing loading. The requirement for a non-metallic airframe dictated a pressure stabilized fiberglass fabric airframe. The long range cruise requirement yielded vehicles of considerable size to obtain the low wing loading. With these considerations, airframe structure weight is a crucial factor in the design. The MC-10 configuration of ZP-253 is based on a restricted launch to allow design only for cruise maneuver requirements or post cruise glide gusts.

All the requirements and assumptions of ZP-253 apply, except for the non-metallic airframe requirement, for the all metal wing. The MC-30 all-metal configuration is, of necessity, a highly refined type of metal construction, with structural requirements quite different from a conventional fighter or bomber aircraft.

The model wing design is a test component representative of the MC-30 construction. The size and support arrangement of the model were recommended by the customer.

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SECTION I

LAUNCH STUDY

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SECTION I

LAUNCH STUDY

Report ZP-253 (Section I, Item D & Section IV, Item 4, Subsection A) discusses the launching methods originally studied for the Hazel vehicles, namely:

1. Rocket launch, sea level to start of cruise.

2. Balloon primary launch to 80,000 feet, secondary rocket boost to start of cruise.

3. Primary launch (carry-up) with conventional aircraft to 45,000 feet, launch with rocket boost to start of cruise.

4. Air breathing special design primary launch to 80,000 feet, secondary rocket boost to start of cruise.

Each of these methods has been considered for the MC-10 configuration and all except method 3 have been eliminated.

Method 1 is impractical for the range and altitude requirements of the mission because of the increased airframe structure weight. This increase is due primarily to two factors: First, a gross weight increase caused by the higher mass ratio required for ground launch. Second, the inherently higher dynamic pressures occuring in the region of maximum wind and gust velocities. This weight increase nullifies the possibility of obtaining any cruise range of consequence, because the light cruise wing loading requirements call for wing areas such that the airframe structure weight growth factor is divergent.

Method 2, the balloon primary assist, has been assumed to be impractical both from a reliability and tactical standpoint, though it might be useful in a test program.

Method 4, the special design airbreathing booster, has not been considered further by direction of the customer.

Launch method 3 has been studied in enough detail to define the major requirements of launching the MC-10 configuration by this means. (MC-10 configuration shown on Figure 1).

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HIGH ALTITUDE PENTABORANE RAMJET MC-10

PRESSURE STABILIZED NON-METALLIC CONSTRUCTION

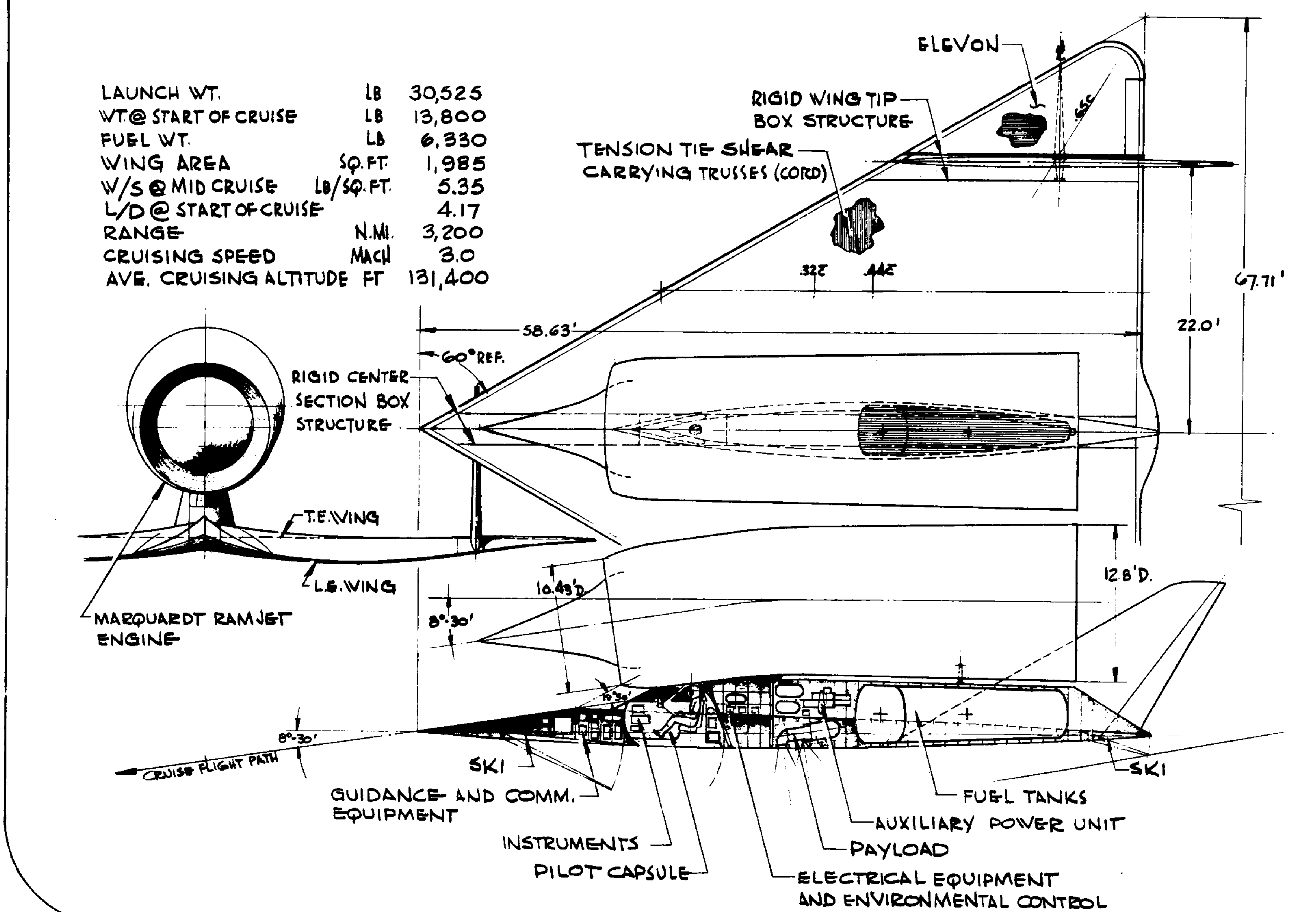

FIG. 1

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The primary or aircraft boost phase of the launch poses a problem similar to that discussed for the sea level rocket launch (Method 1). The large wing area of the cruise vehicle, in conjunction with the relatively heavy wing loading response of the booster aircraft combination, can produce wing gust airloads greater than either the start of cruise maneuver airloads (with temperature losses) or the glide airloads after cruise. Rudimentary checks of convective gust velocities of $50/\sqrt{\sigma}$ f.p.s. below 25,000 feet altitude (Ref. Page 76 of ZP-253) indicate speed restrictions below the minimum flying speed of a B-36 or B-52 type aircraft would be required in order to limit gust airloads to equal the start of cruise or post cruise design loads.

Figures 2, 3, 4 & 5 illustrate the method studied to permit aircraft boost without cruise vehicle airframe penalty beyond cruise requirements. The entire vehicle wing is in contact with the upper surface of a support platform. The platform is made structurally adequate to support itself and the attached vehicle and any applied airloads. The vehicle is attached to the support platform by locating pins and a pressure differential maintained between the wing lower surface and platform upper surface. The platform upper surface is envisioned as a sandwich panel with a perforated upper skin and honeycomb core manifolded to a vacuum pump. A suitable seal would be used around the perimeter to prevent excessive leakage.

The airloads applied to the vehicle wing would be reacted directly from the wing upper surface, thru the wing sub structure, to the platform panel, and then thru the platform substructure to the booster aircraft. This relieves the vehicle wing structure of the shears and bending moments imposed by the airloads.

Just prior to separation the booster aircraft will be slowed to near minimum speed. The separation for the secondary rocket launch would be accomplished by the simultaneous pressure release of the vehicle as booster thrust buildup occurs. The guide pins would help maintain proper vehicle relationship to the carrier aircraft during initial separation. The swiveling first stage rocket motors are positioned to lift the MC-10 vehicle away from the carrier aircraft with enough forward thrust component to nullify drag and give a small horizontal acceleration away from the carrier vertical tail surface.

Preliminary checks have indicated that for a structure design predicated on the cruise and post cruise requirements only, the allowable load factor at separation would be .97 G limit. With a zero lift

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FIG. 2

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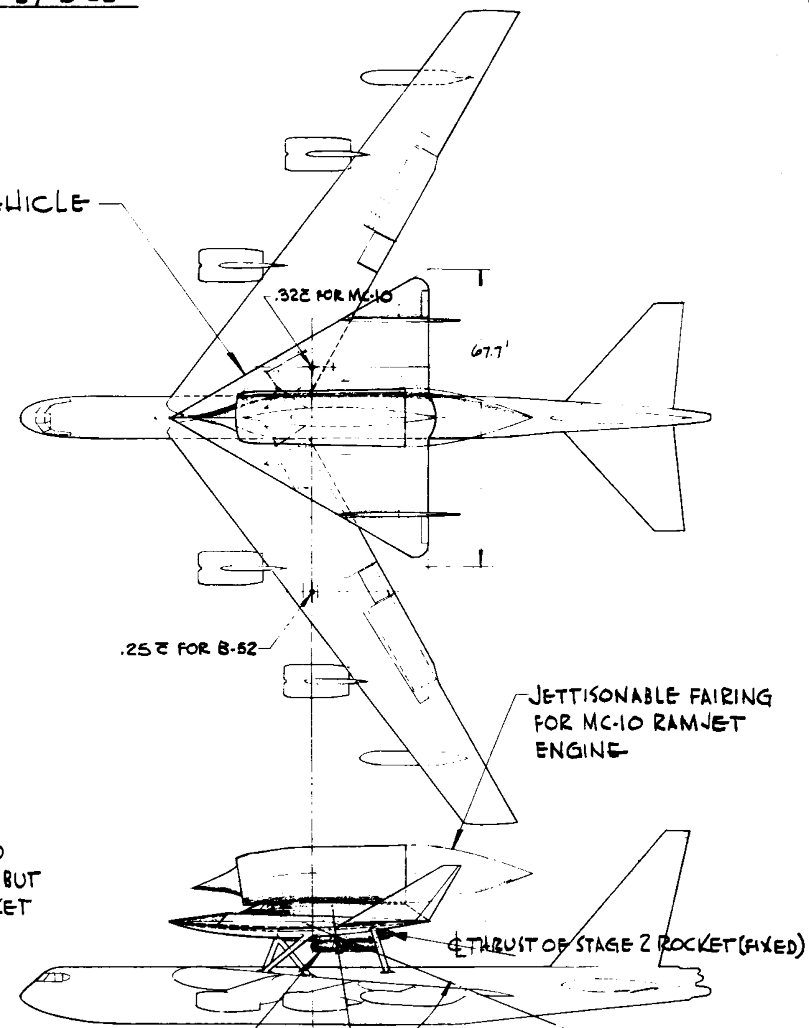
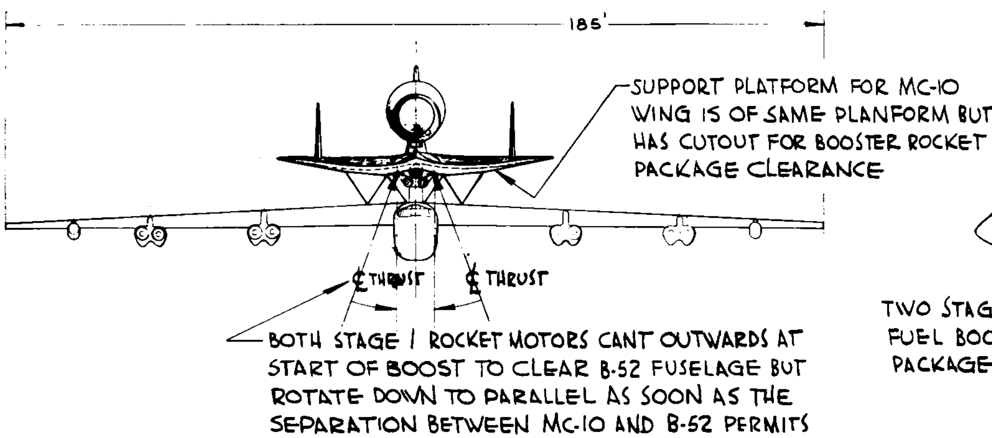
'ZERO LIFT' AIR LAUNCHING CONFIGURATION

MC-10 VEHICLE CARRIED BY B-52

WEIGHTS FOR MC-10 VEHICLE AND BOOSTER ROCKETS

LAUNCH (START OF STAGE 1)	35,000 LB.
STAGE 1 BURNOUT	26,478 LB.
START OF STAGE 2	24,762 LB.
STAGE 2 BURNOUT	15,612 LB.
START OF CRUISE	13,800 LB.





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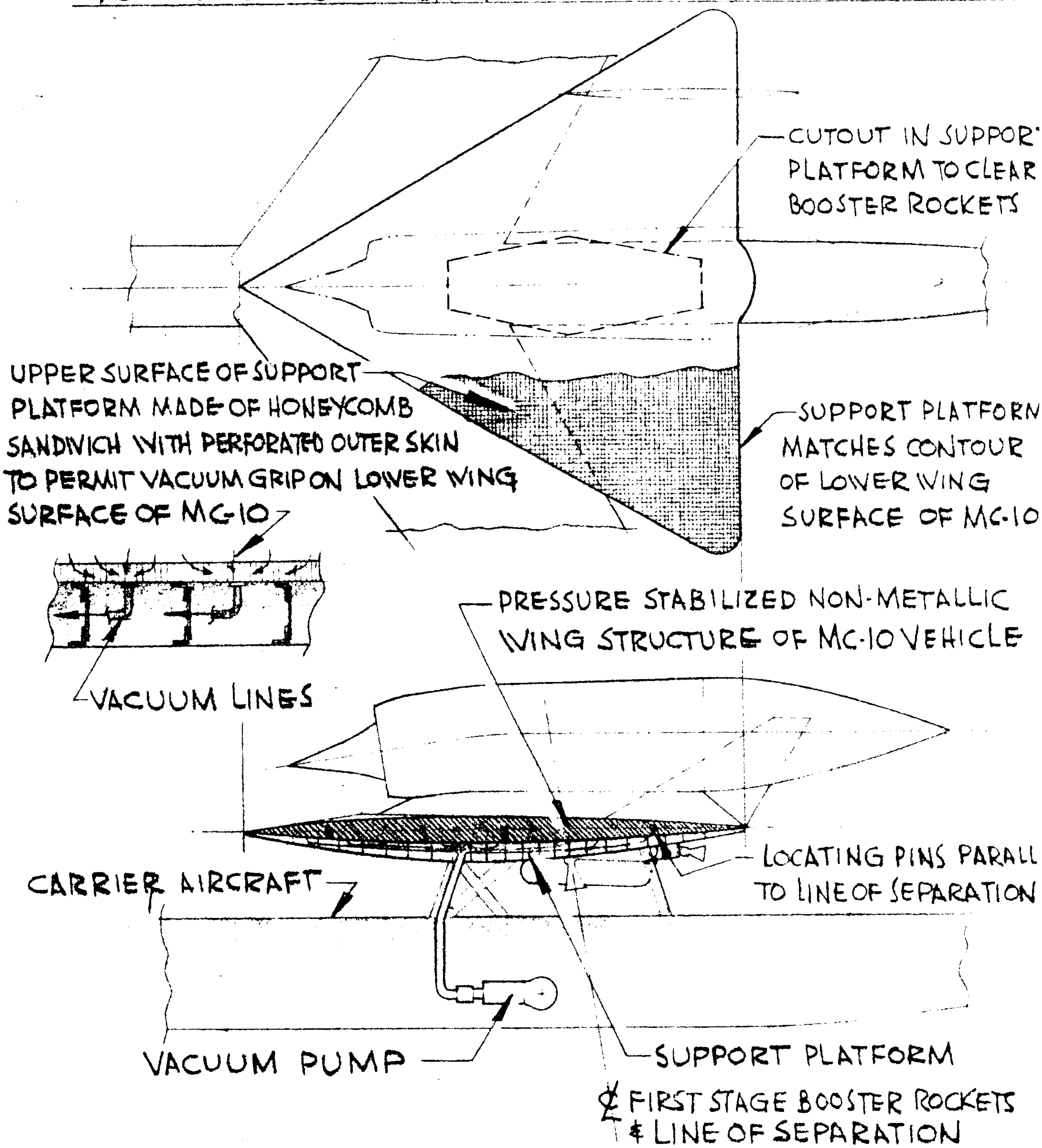
METHOD OF ATTACHING MC-10 VEHICLE TO SUPPORT PLATFORM ON CARRIER AIRCRAFT



THE VACUUM GRIP METHOD OF ATTACHMENT PREVENTS MC-10 WING FROM SUSTAINING AIRLOAD DURING CARRIER AIRCRAFT FLIGHT UP TO LAUNCH ALTITUDE AND PERMITS INSTANT RELEASE AT LAUNCH.

FIG. 3

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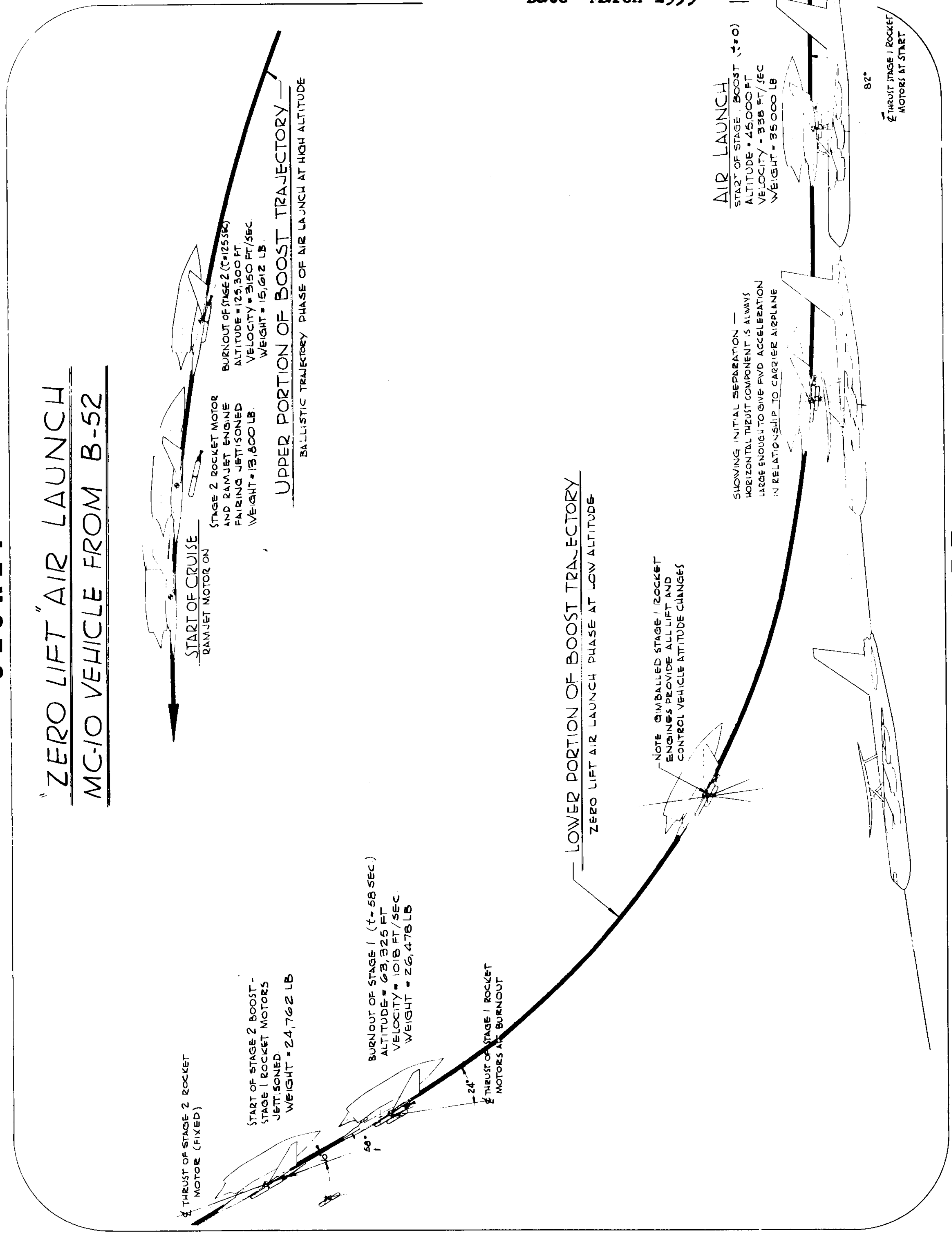

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FIG. 4

ZERO LIFT AIR LAUNCH-MC-10 OR MC-30 VEHICLE FROM B-36 CARRIER AIRCRAFT

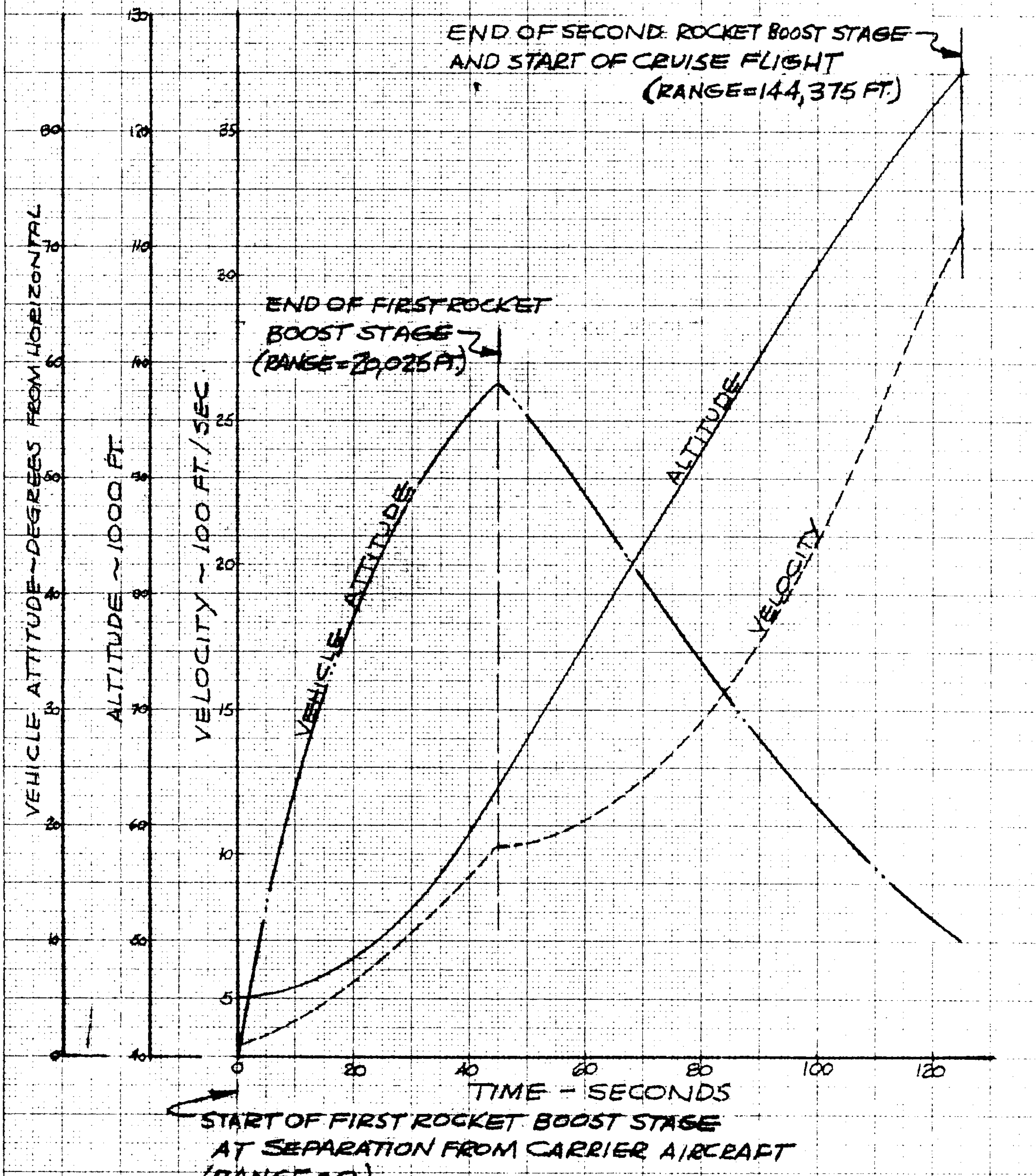

FIG. 5

launch, the only expected wing airloads would be gust airloads. To insure the structure against gust airload overloading, the vehicle true airspeed would have to be limited such that conservative gust criteria would not produce airloads beyond limit design. Figure 7 is a plot of the expected limits based on the gust velocity criteria of Page 76 in Report ZP-253.

It should be noted that Figure 7 indicates a first stage trajectory outside the gust limits in a small area. It has been assumed that this discrepancy can be removed by further launch trajectory investigation. The trajectory shown is a typical performance based on first approximations, with time not permitting further study.

The initial separation is assumed to be made at 45,000 feet and at a true airspeed of 200 knots (dynamic pressure of 30 psf). As the first stage thrust vector program rotates the vehicle and begins the climb and acceleration, the speed increase is offset by a reducing gross weight and air density in addition to a lowering of gust velocities to a point where at 75,000 feet, gust airloads are no longer of any importance. As illustrated in Figure 7, during the second stage of the rocket launch, the magnitude of the possible gust load has diminished to a point where aerodynamic trajectory control is used, permitting a non-gimballed second stage.

The secondary portion of the vehicle boost is also difficult to do without penalty beyond the cruise and landing requirements. The large gross weight resulting from the booster package weight in addition to full cruise fuel weight severely limits the airload capability of the vehicle after separation from the booster aircraft. The gross weight requirements are particularly penalyzing to the cruise vehicle because of the lack of inertia relief in the wings, since both the booster package and cruise fuel are of necessity at or in the body.

Investigation of a conventional aerodynamic launch from the booster aircraft in which the cruise vehicle flies away from the booster air- and then performs a pullup maneuver for initiation of the rocket boost has indicated this method to be impossible within the ground rules of altitude and range. Appendix A discusses the effect of the weight growth resulting from the 2G pullup maneuver in the presence of gusts at separation. The MC-10 non rigid vehicle could never fulfill the range requirements if designed for this criteria. (See Figure 18).

Figure 6 is an approximation of the optimum structural system for least weight versus design load (gross weight and load factor) and wing area. When the design requirements plot significantly into one systems area, large weight differences occur if the opposite system is considered.

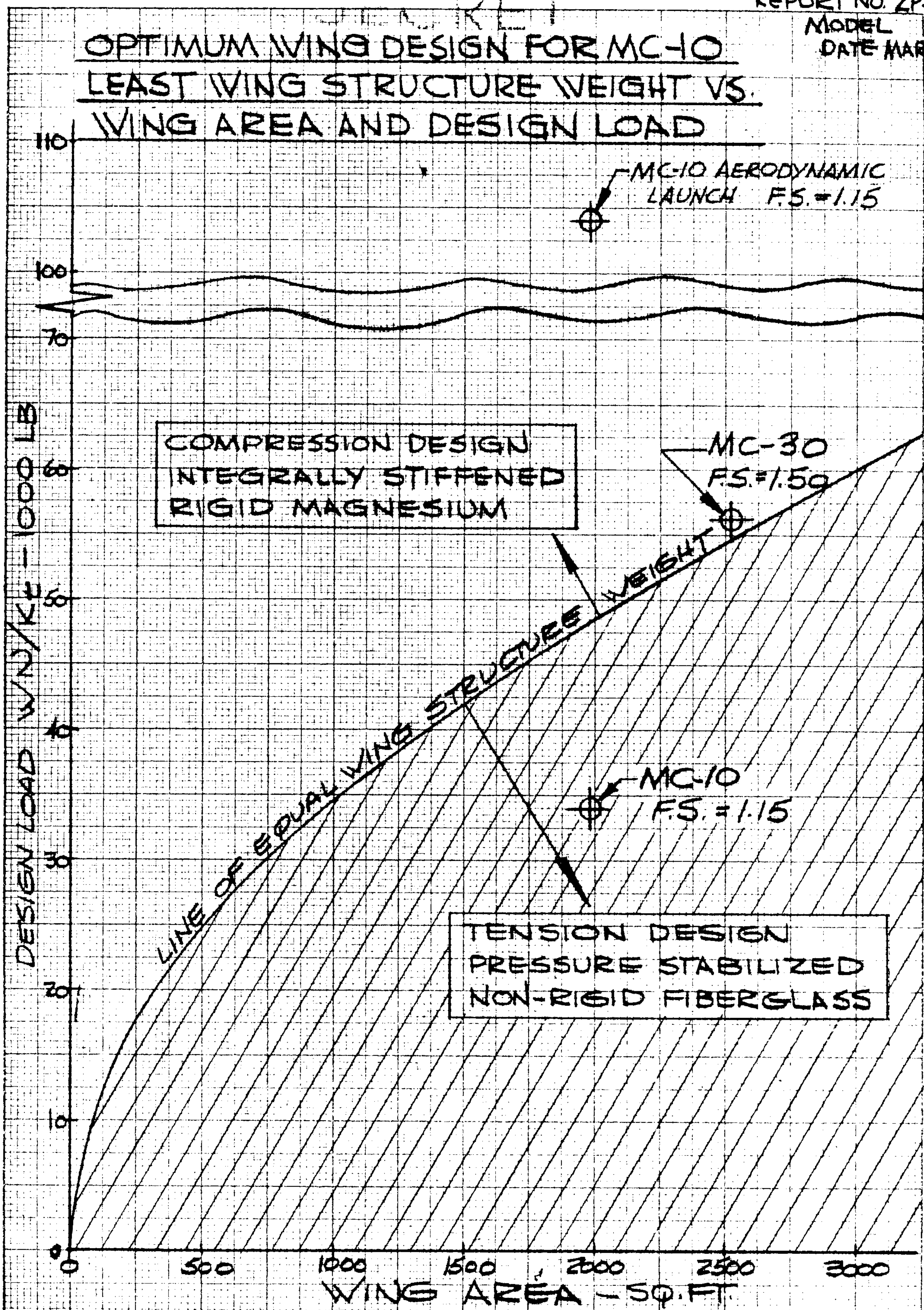
OPTIMUM WING DESIGN FOR MC-10
LEAST WING STRUCTURE WEIGHT VS.
WING AREA AND DESIGN LOAD
MC-10 AERODYNAMIC LAUNCH F.S.=1.15
COMPRESSION DESIGN
INTEGRALLY STIFFENED
RIGID MAGNESIUM
MC-30
F.S.=1.5g
LINE OF EQUAL WING STRUCTURE WEIGHT
MC-10
F.S.=1.15
TENSION DESIGN
PRESSURE STABILIZED
NON-RIGID FIBERGLASS
DESIGN LOAD WN/KE - 1000 LB
WING AREA - SQ.FT
0
10
20
30
40
50
60
70
100
110
500
1000
1500
2000
2500
3000

FIG. 6

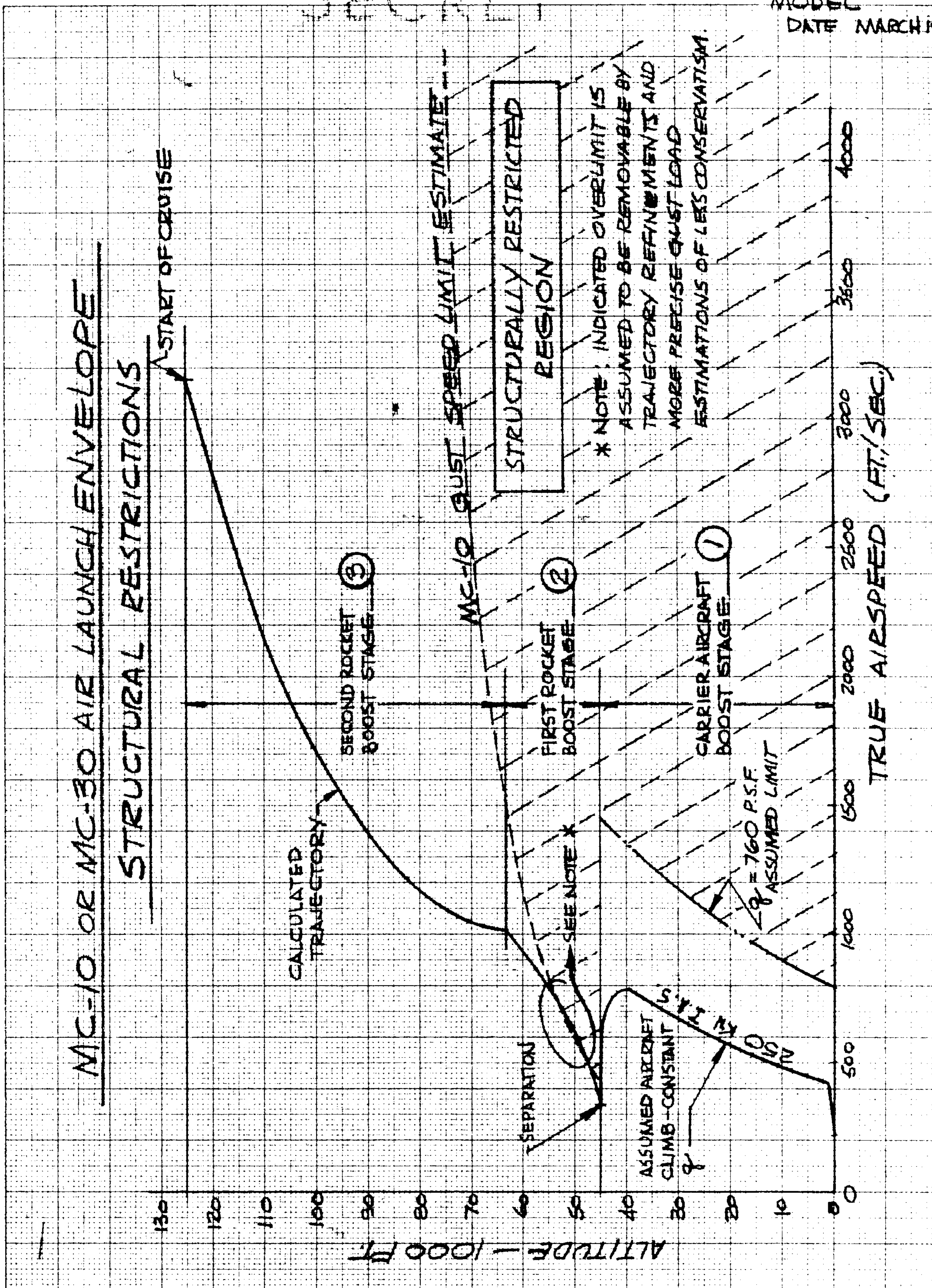
MC-10 OR MC-30 AIR LAUNCH ENVELOPE
STRUCTURAL RESTRICTIONS
START OF CRUISE
CALCULATED TRAJECTORY
SECOND ROCKET BOOST STAGE ③
FIRST ROCKET BOOST STAGE ②
CARRIER AIRCRAFT BOOST STAGE ①
MC-10 GUST SPEED LIMIT ESTIMATE
STRUCTURALLY RESTRICTED REGION
* NOTE: INDICATED OVERLIMIT IS ASSUMED TO BE REMOVABLE BY TRAJECTORY REFINEMENTS AND MORE PRECISE GUST LOAD ESTIMATIONS OF LESS CONSERVATISM.
SEE NOTE *
SEPARATION
ASSUMED AIRCRAFT CLIMB-CONSTANT q
q = 760 P.S.F. ASSUMED LIMIT
V_{NO}
ALTITUDE — 1000 FT
TRUE AIRSPEED (FT./SEC.)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
500
1000
1500
2000
2500
3000
3500
4000

FIG. 7

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This is what happens to the MC-10 configuration when designed for the aerodynamic launch. The design loading and wing area makes the pressure stabilized approach a penalty.

The secondary launch considered is a two stage rocket powered boost. The first stage is a zero lift ballistic trajectory using programmed thrust vectoring for lift and inertial attitude control as well as propulsion.

As the vehicle approaches cruise speed and altitude, it begins to be aerodynamically heated. When it reaches final staging, the vehicle is capable of a maneuver load factor of $\pm$ 1.5 G limit, with increasing capability as cruise fuel is burned. This capability (1.5G at start and 2.1G at end) allows maneuvering as desired during cruise at temperature.

To summarize, the launching system requires a three stage boost from ground to start of cruise. The primary portion is an aircraft boost from the ground to 45,000 feet, using a modified existing aircraft with a special platform support. The second phase is a two stage rocket launch, first stage a zero lift gimbaled rocket boost to 63,000 feet, and a final rocket boost with lift to start of cruise. All other methods considered have been ruled out either by practical considerations or the physical limitations imposed by the design and mission requirements.

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SECTION II

ALL METAL AIRFRAME CONFIGURATION

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SECTION II

ALL METAL AIRFRAME CONFIGURATION

The initial vehicle studies made in Report ZP-253, were based on a primary requirement for a non-metallic airframe. The outgrowth of this basic restriction was the concept of a non rigid, pressure stabilized impregnated fiberglass wing structure in combination with a conventional rigid reinforced plastic body and pylon which is the MC-10 configuration as shown in Figure 1. The pressure stabilizing was utilized in conjunction with the non rigid airframe concept to accomplish two major goals: First, for minimal airframe requirements, non rigid construction offers the lightest producibility limits. Secondly, to save weight, a reduced factor of safety was proposed on the premise of the non destructive load limiting ability of the non rigid, pressure stabilized structure.

In this re-evaluation, the non-metallic requirement is removed, which allows the consideration of high efficiency metal construction. The same structural design criteria, as summarized in Table I is assumed to apply along with the original overall mission requirements. However, since the metal construction considered is "conventional" rigid structure, the normal factor of safety for manned aircraft of 1.50 for ultimate loads is used in the MC-30 rigid metal configuration along with the normal structure design requirements, as outlined in MIL-A-8629 "Airplane Strength and Rigidity", where applicable.

Figure 8 shows the MC-30 configuration. This configuration is identical to the MC-10 configuration except for a size increase proportional to the vehicle weight difference. The basic geometrical relationships, arrangements, and crossections are held. Table 2 is a comparative weight breakdown for the two configurations.

The major airframe component of the MC-30 vehicle is the wing structure. The body structure as such is the center portion of the wing and the engine support pylon. All fuel, equipment, payload and crew are placed in this "body" pylon area, thus placing almost 85% of the vehicle mass along the vehicle centerline or wing root section. The body-pylon structure is assumed to be primarily composed of the wing root section and two main ribs providing longitudinal stiffness and torsional continuity for unsymmetrical wing loads.

TABLE I

STRUCTURAL DESIGN CRITERIA FOR MC-10 AND MC-30 VEHICLES

CONDITION	WEIGHT COND.	VELOCITY KNOTS (B)	ALTITUDE 1000 FT. (B)	q LB/SQ.FT. (B)	STRUCTURE TEMP. 10FT AFT OF L.E. DEG.F (B)	LOADING APPLICATION	REACTION	N_z LIMIT G	N_y LIMIT G	N_x LIMIT G
I. HANDLING										
A. TRANSPORT	GLIDE	—	—	—	+70 TO -65	VEHICLE INERTIA	SUPPORT JIG	+2.00	±1.00	±1.00
B. HOIST-JACK	GLIDE	—	—	—	+70 TO -65	VEHICLE INERTIA	SUPPORT JIG	+2.00	±1.00	±1.00
II. LAUNCH										
A. PRIMARY (BY CARRIER A/C)	SECONDARY LAUNCH	(THE PRIMARY LAUNCH – VEHICLE CARRIED UP TO THE AIR LAUNCH ALTITUDE – IS ARRANGED SO THAT THE VEHICLE CAPABILITIES OF (A) WILL NOT BE EXCEEDED)								
B. SECONDARY-START	SECONDARY LAUNCH	280	45	52	250	GUST AIRLOAD	VEHICLE INERTIA	+.97 (C)	—	—
C. SECONDARY-END	SECONDARY BURNOUT	1865	125	52	305	THRUST	VEHICLE INERTIA	+1.50	+.50	-2.00
III. CRUISE										
A. BEGIN TURN (A)	START CRUISE	1865	125	52	305	AIRLOAD	VEHICLE INERTIA	$+2.14K_t$ (D)	$\pm.25K_t$ (D)	—
B. MID TURN	MID CRUISE	1880	132	41	305	AIRLOAD	VEHICLE INERTIA	$+2.79K_t$	$\pm.25K_t$	—
C. END TURN	END CRUISE	1920	140	28	305	AIRLOAD	VEHICLE INERTIA	$+3.0K_t$	$\pm.50K_t$	—
IV. GLIDE										
A. MANEUVER (A)	GLIDE	1680	85	275		AIRLOAD	VEHICLE INERTIA	+3.00 −1.50	±.50	—
B. GUST (A)	GLIDE	150	35	28		GUST AIRLOAD	VEHICLE INERTIA	+3.00 −1.50	±.50	—
V. LANDING										
A. MAX. SINK	GLIDE	40	S.L.	28		SKI WATERLOAD	VEHICLE INERTIA	+3.00	±.50	±.50
B. WORST ATTITUDE	GLIDE	40	S.L.	28		SKI WATERLOAD	VEHICLE INERTIA	+2.00	±1.00	±.50
VI. RECOVERY										
	GLIDE	ASSUME SAME AS HANDLING								

(A) BASIC STRUCTURAL DESIGN CONDITIONS
(B) TYPICAL VALUES FOR REFERENCE
(C) ASSUMES ZERO LIFT LAUNCH TRAJECTORY
(D) K_t = STRENGTH LOSS @ TEMPERATURE

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HIGH ALTITUDE PENTABORANE RAMJET

MC-30

STIFFENED PANEL ALL METAL CONSTRUCTION

LAUNCH WT.	LB	38,700
WT. @ START OF CRUISE	LB	17,500
FUEL WT.	LB	8,045
WING AREA	SQ. FT.	2,520
W/S @ MIDCRUISE	LB/SQ. FT.	5.35
L/D @ START OF CRUISE		4.17
RANGE	N.MI.	3,200
CRUISING SPEED	MACH	3.0
AVE. CRUISING ALTITUDE	FT.	131,400

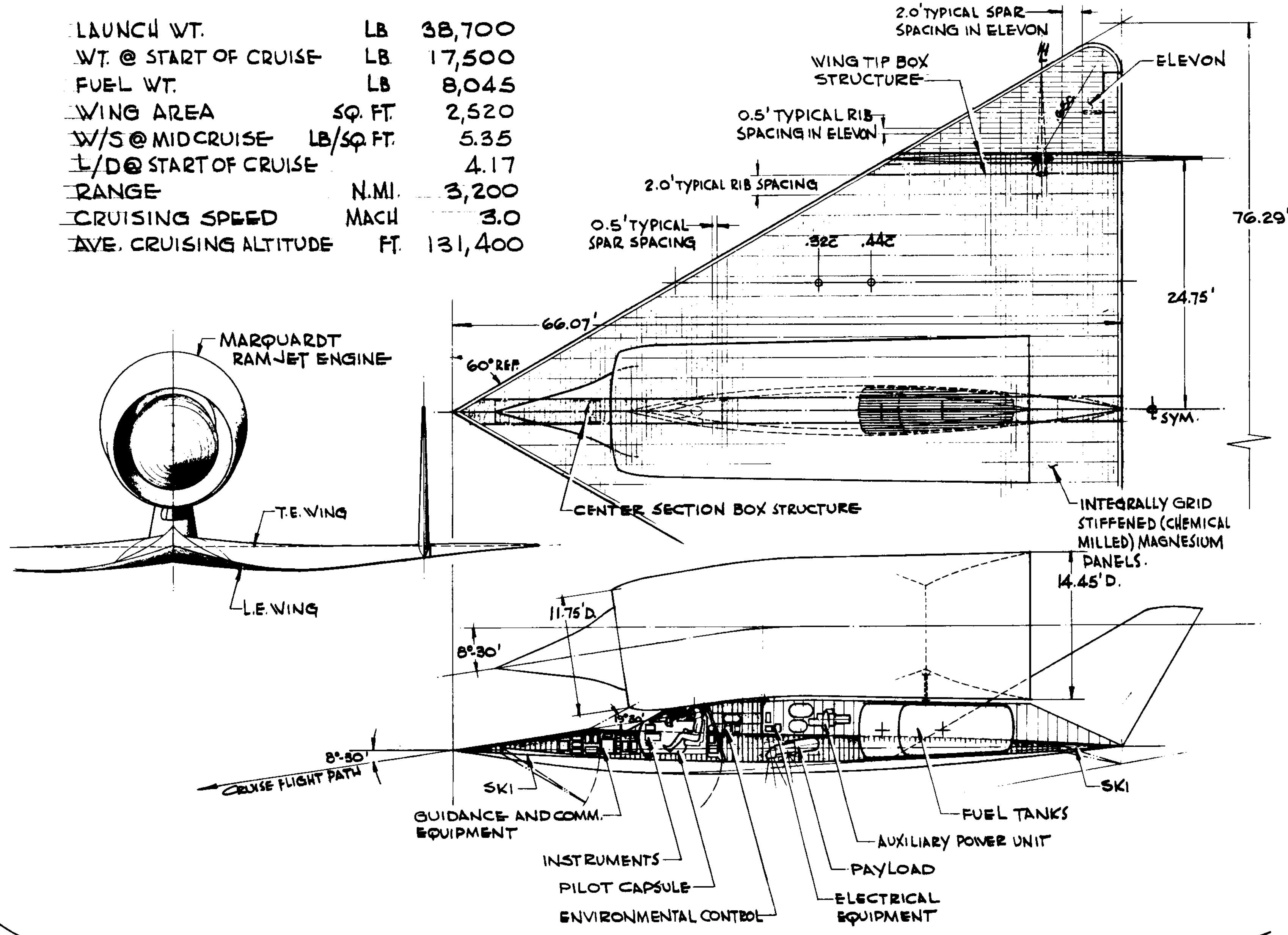

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FIG. 8

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TABLE 2

WEIGHT COMPARISON

BETWEEN MC-10 PRESSURE STABILIZED NON-METALLIC VEHICLE AND MC-30 ALL METAL VEHICLE

	MC-10 LB.	MC-30 LB.
STRUCTURE	2,635	4,329
SPECIAL FINISH	68	--
ENGINE	1,460	1,820
FIXED EQUIPMENT	2,307	2,306
CREW	200	200
PAYLOAD	800	800
GLIDE WEIGHT	7,470	9,455
FUEL	6,330	8,045
START OF CRUISE WEIGHT	13,800	17,500
BOOSTER	16,725	21,200
AIR LAUNCH WEIGHT	30,525	38,700

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The basic wing structure is assumed to be a full cantilever, multi-spar, isotropically stiffened panel arrangement, with attached vertical fins of the same construction. The flying wing tip control surfaces are multi-rib, isotropically stiffened panel structures with a single spar box terminating in a pivot shaft. This pivot shaft is supported on two bearings in a chordwise torque box at the fin attachment in the wing which redistributes both the fin bending moments and the wing tip bending moments to the wing skins. (See Figure 8).

Multi-spar, stiffened panel wing and fin construction was selected for several reasons: First, the aircraft arrangement permits full spar and panel carry thru except at the crew compartment. Secondly, the delta planform geometric advantage is used most efficiently with all wing bending loads carried in the wing skins operating to the plate buckling allowable of an infinite length panel, rather than buckling skins with a few heavy stabilized spars. Also, aerolastic advantages exist with the stiffened panel multi-spar arrangements, particularly in relatively lightly loaded, large delta wings. Classic flutter problems, although not necessarily a problem in high sweep delta wings, are virtually eliminated by the stiffness, both in bending and torsion, that results from the stiffened panel skins. Panel flutter problems, which become increasingly important with large area lightly loaded wings, are also eliminated with the panels stiffened to resist bending loads. Thermal stresses, where high heat flux densities are anticipated, can be a problem with stiffened panels unless adequate relief is provided in the sub structure. Fatigue problems are reduced in the multi-spar, stiffened panel by the general lowering of the operating stress levels. Also, the reliability, where fatigue or other local failures might occur, is greatly enhanced with the high degree of redundancy present in the structure. Smoothness of wing skins is also obtained (even to ultimate load) by the stiffened panels, which is important for a long range cruise vehicle.

The basic panel configuration assumed is an integral grid stiffened panel with appropriate integral pads for substructure attachment, manufactured by precision chemical etching from ground plate stock to obtain minimal tolerance accumulations. Panel splices would be accomplished spanwise at a spar by butt splicing with a splice plate. Figure 17 of the model detail is a representation of the full scale components also and can be used for illustration.

The primary substructure assumed is closely spaced span-wise spars (6.0 in.) and widely spaced ribs (24.0 in.) made from corrugated webs with minimum continuity attachment caps. The scalloped leg channel caps

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provide for the shear connection to the corrugated webs and the panel attachment, with all bending loads carried in the panel. Maintenance of the extensional flexibility of the substructure components is important so that panel thermal expansion under high heat inputs will not generate large panel compressive stresses or substructure tensile stresses. The corrugated webs and scalloped caps meet this requirement in addition to providing an efficient shear web and panel stabilizing support.

The perimeter structure, i.e., leading edge, trailing edge and tips, is assumed to be of a full sandwich construction to obtain the very sharp radii desired for the vehicle cruise performance. Built up structure can be utilized if thermal stress problems can not be overcome in the sandwich structures. The juncture between the perimeter structure and basic airframe would also provide a convenient splice point for replacing damaged perimeter components. Replacability could be of particular importance for the leading edge because of the higher temperatures present there.

Figure 9 shows equilibrium temperatures in the airframe during cruise. The temperature at 10 foot aft of the leading edge is used as the basic airframe temperature exposure. The life design temperatures are those resulting from normal operation for an assumed 667 fullrange missions or 1000 hours at cruise speed and altitude (approximately 1.5 hours/mission). The short time limit is an additional requirement to account for short periods of operation off of design speed or altitude which could occur for any reason. This has also been arbitrarily assumed as 100 hours based on 9 minutes per mission for 667 missions. Figure 10 is an information plot of the effects of altitude and speed on the equilibrium temperatures of a cruise vehicle, illustrating the off design permissable limits among other things.

The material requirements have been predicated on the usual structural criteria of less than .2% permanent set at limit load and no failure before 1.5 X limit load is applied. The MC-30 requirements pose additional material requirements, however, due to the long exposure to elevated temperature and the need for adequate strength at normal temperature after the elevated temperature exposure.

The criteria for the primary airframe is based on plate buckling allowable stress if this is lower than either the rupture stress or stress that would produce .5% total deformation in 1000 hours at 305°F. during cruise at 1.25 G. For the launch and post cruise requirements, the plate buckling allowable stress is again used as long as it is lower than the

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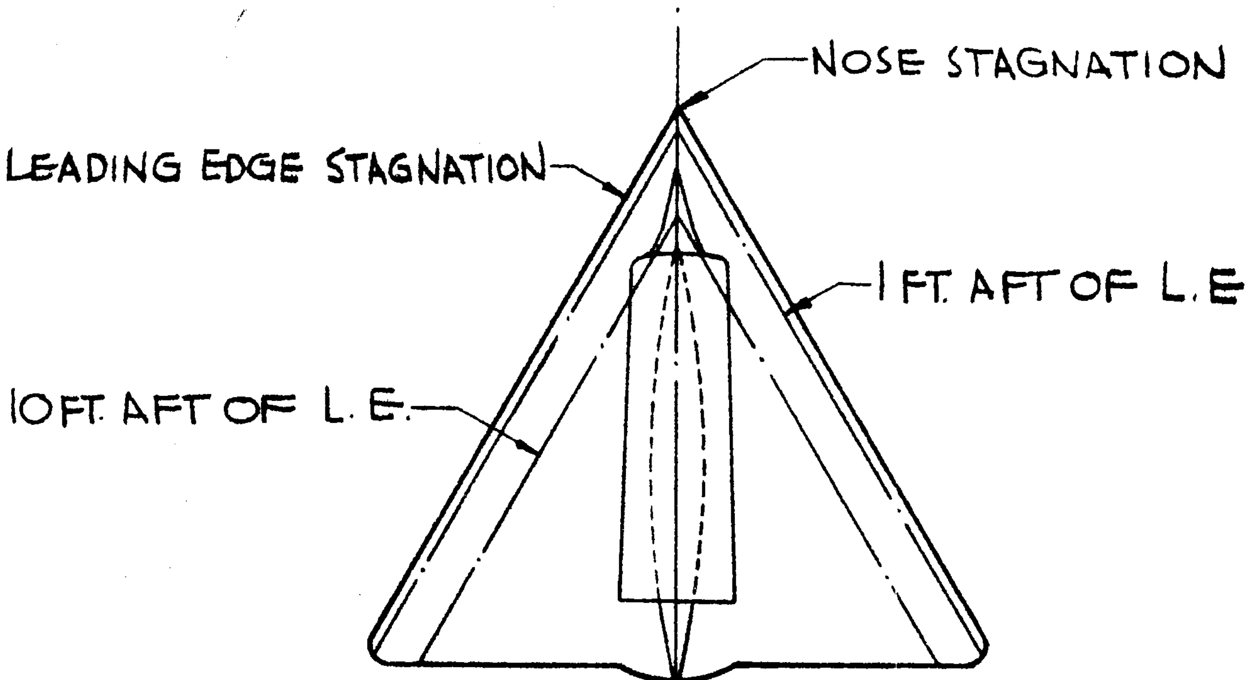
FIG. 9

TYPICAL TEMPERATURE DISTRIBUTION FOR THE MC-30 VEHICLE



CRUISE ANGLE OF ATTACK = 10°, ε = .8, DAYLIGHT

		LIFE DESIGN ②			SHORT TIME LIMIT ③		
		SPEED MACH.	ALTITUDE FT.	TEMPERATURE DEG. F	SPEED ① MACH	ALTITUDE ① FT.	TEMPERATURE DEG. F
NOSE STAGNATION		3	135,000	725	3.9	135,000	815
L.E. STAGNATION				630			685
1 FT. AFT OF L.E.				400			550
10 FT. AFT OF L.E.	UPPER SURFACE			305			425
	LOWER SURFACE	3	135,000	291	3.9	135,000	—

① CHOSEN AS EXAMPLE OF OFF DESIGN OPERATION
② 1000 HRS. OF CRUISE (667 1½ HR. FULL RANGE MISSIONS)
③ 100 HRS. ACCUMULATED AT 9 MINUTES PER FLIGHT.

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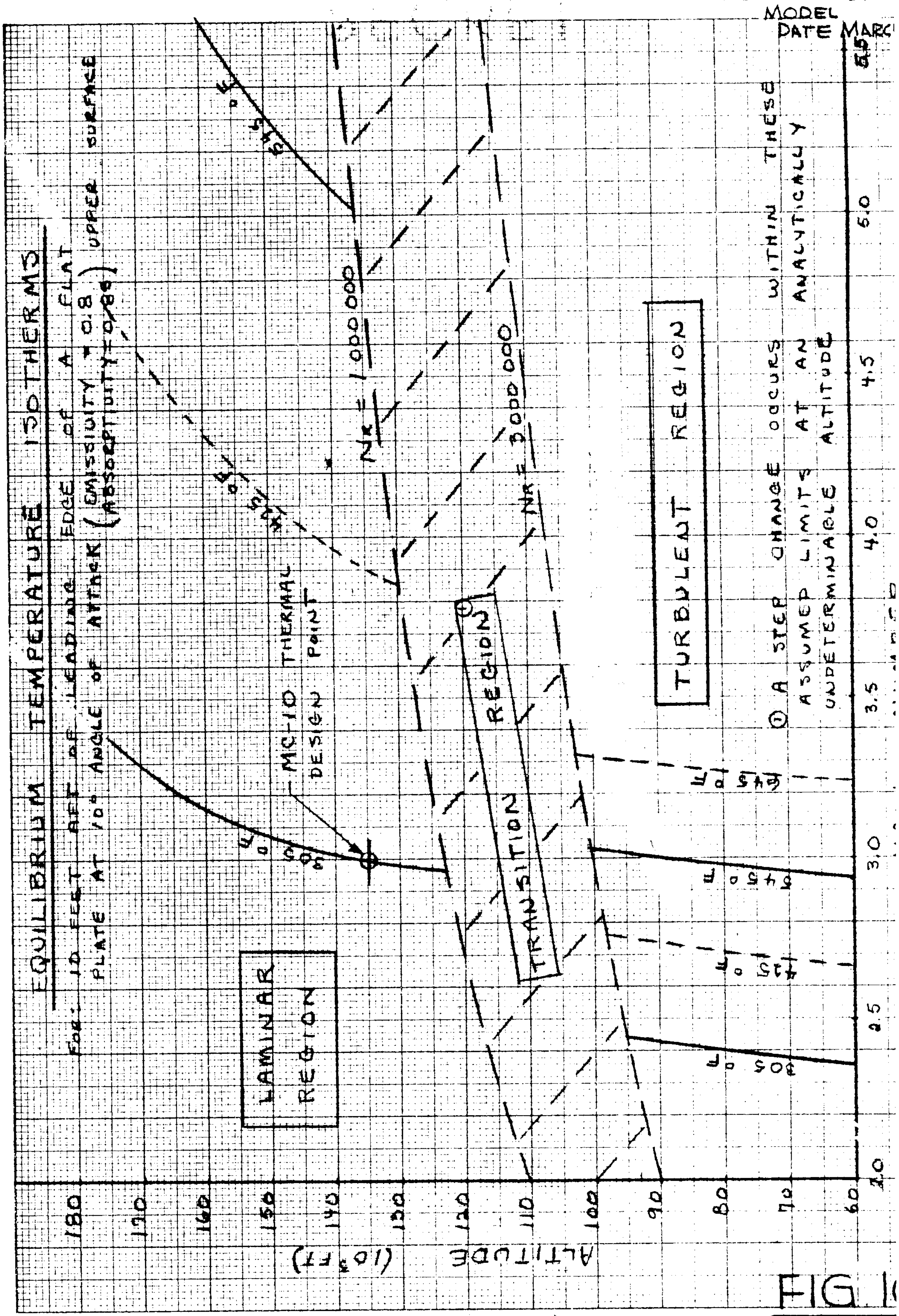
EQUILIBRIUM TEMPERATURE ISOTHERMS
FOR: 10 FEET AFT OF LEADING EDGE OF A FLAT PLATE AT 10° ANGLE OF ATTACK (EMISSIVITY = 0.8) (ABSORPTIVITY = 0.80) UPPER SURFACE
LAMINAR REGION
TRANSITION REGION
TURBULENT REGION
MC-10 THERMAL DESIGN POINT
Nr = 1,000,000
Nr = 3,000,000
① A STEP CHANGE OCCURS WITHIN THESE ASSUMED LIMITS AT AN ANALYTICALLY UNDETERMINABLE ALTITUDE
ALTITUDE (10³ FT)
180
170
160
150
140
130
120
110
100
90
80
70
60
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5

FIG 1(

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allowable stress remaining at normal temperature after exposure to 1000 hours at 305°F. and 100 hours at 425°F., both at 1.25 G. Plate buckling allowables in both cases include the thermal effect on modulus of elasticity.

The material selection for the MC-30 airframe is based on the optimum strength to weight ratio obtainable for this configuration. Figure 11 is a plot of various material strength to weight ratios predicated on the MC-30 requirements of panel buckling strength or elevated temperature criteria. Loading intensity, panel geometry, panel edge fixity and panel stiffness ratios are equal for all materials and are those of the MC-30 configuration. The web requirements of the spars and ribs have been assumed to vary in a manner similar to the panel requirements, since the relatively low loading intensities would yield webs designed for shear stability. Shear stability is identical to compressive panel stability in being a function of modulus of elasticity and material bulk.

A thorium alloy of magnesium was chosen for the airframe structure sheet or plate requirements, HK31A-H24. This is a production alloy and is readily formed, welded and riveted. Those parts that would be extruded or machined from bar stock have been assumed to be made from a zinc, zirconium alloy of magnesium, ZK60A-T5, also a production alloy produced by the Dow Chemical Company. Again, figure 17 of the model wing details illustrates full scale details and materials of the MC-30 configuration. Figure 12 contains typical mechanical properties data at elevated temperature for HK31A-H24.

Figure 13 is an extrapolation from the MC-30 design point in terms of wing size and wing structural loading effects on wing structure weight. The basic configuration weight was calculated from a design breakdown of the individual static stress analysis area requirements along with the following simplified assumptions; some of which are conservative and other unconservative:

1. Uniform airload distribution with C.P. at 33% of the semi span and 50% of the chord.

2. Neglect wing inertia relief.

3. Wing section is a double wedge airfoil with zero radius edges.

4. Overall wing bending panel requirement is established by the root moment applied uniformly to 2/3 of the root chord at the root average depth.

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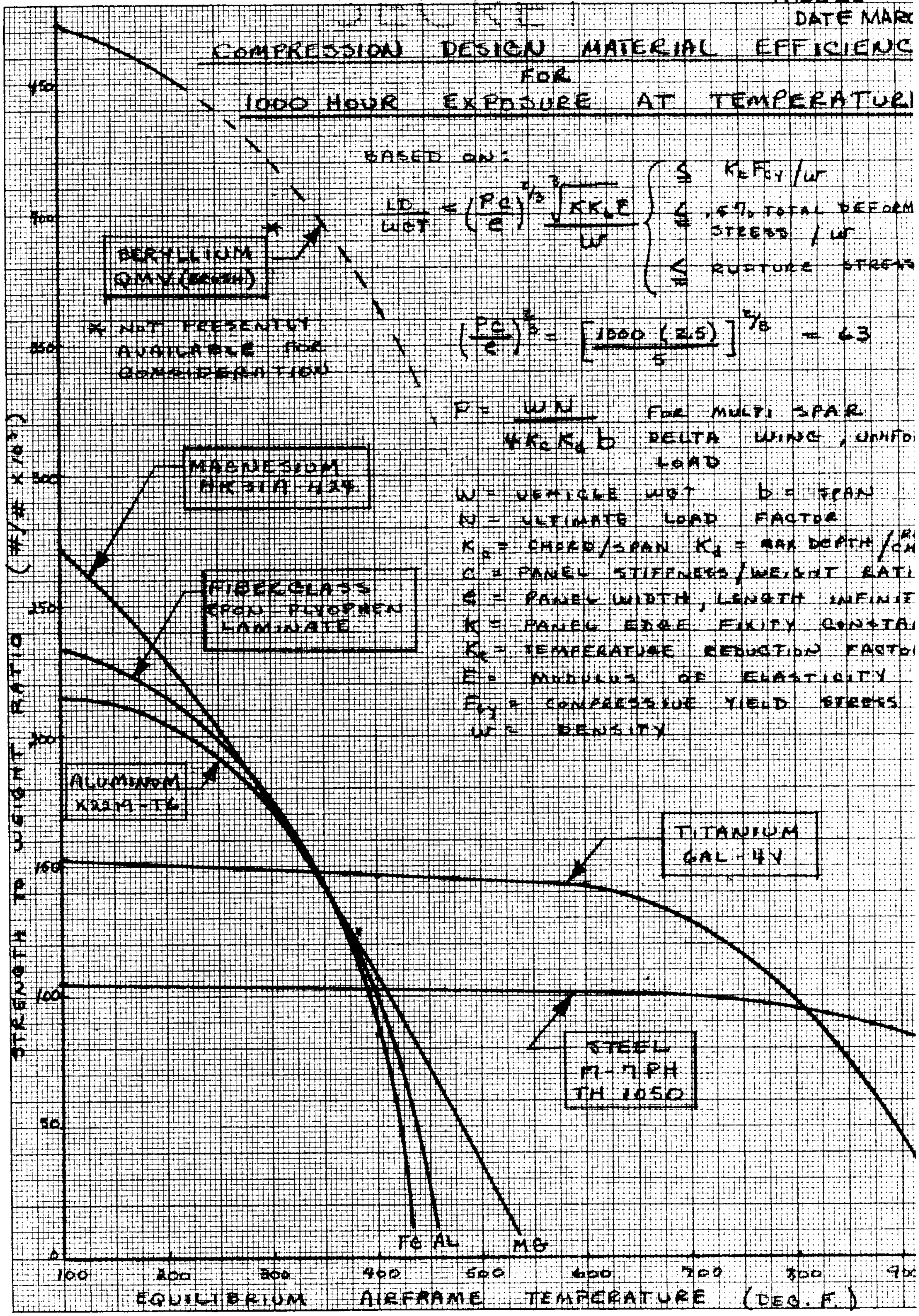
COMPRESSION DESIGN MATERIAL EFFICIENC
FOR
1000 HOUR EXPOSURE AT TEMPERATUR
BASED ON:
$\frac{LD}{WGT} = \left(\frac{Pc}{\epsilon}\right)^{2/3} \frac{\sqrt[3]{KK_eF}}{w}$
≤ K_eF_{cy}/w
≤ .5% TOTAL DEFORM STRESS / w
≤ RUPTURE STRESS
$\left(\frac{Pc}{\epsilon}\right)^{2/3} = \left[\frac{1000\ (2.5)}{5}\right]^{2/3} = 63$
$P = \frac{WN}{4K_cK_d\ b}$ FOR MULTI SPAR DELTA WING, UNIFO LOAD
W = VEHICLE WGT b = SPAN
N = ULTIMATE LOAD FACTOR
K_c = CHORD/SPAN K_d = MAX DEPTH / CH
C = PANEL STIFFNESS / WEIGHT RATI
ε = PANEL WIDTH, LENGTH INFINIT
K = PANEL EDGE FIXITY CONSTA
K_e = TEMPERATURE REDUCTION FACTO
E = MODULUS OF ELASTICITY
F_{cy} = COMPRESSIVE YIELD STRESS
w = DENSITY
BERYLLIUM QMV (BRUSH)
* NOT PRESENTLY AVAILABLE FOR CONSIDERATION
MAGNESIUM HK31A H24
FIBERGLASS EPON PLYOPHEN LAMINATE
ALUMINUM X2219-T6
TITANIUM 6AL-4V
STEEL PH-7PH TH 1050
FE AL MG
STRENGTH TO WEIGHT RATIO (#/# × 10³)
450
400
350
300
250
200
150
100
50
0
100 200 300 400 500 600 700 800 900
EQUILIBRIUM AIRFRAME TEMPERATURE (DEG. F.)

FIG. 11

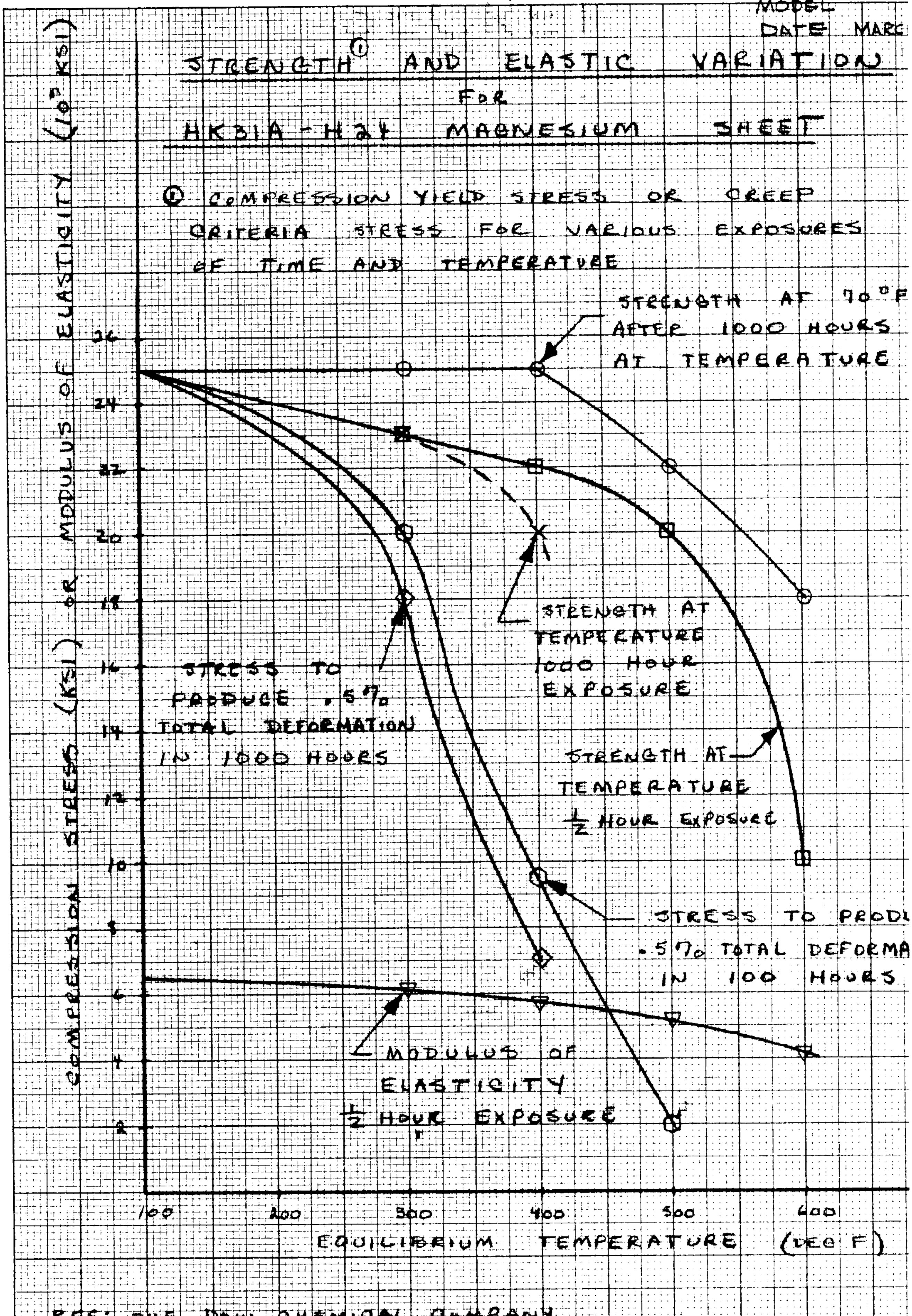
STRENGTH (1) AND ELASTIC VARIATION
FOR
HK31A-H24 MAGNESIUM SHEET
(1) COMPRESSION YIELD STRESS OR CREEP CRITERIA STRESS FOR VARIOUS EXPOSURES OF TIME AND TEMPERATURE
COMPRESSION STRESS (KSI) OR MODULUS OF ELASTICITY (10^3 KSI)
STRENGTH AT 70°F AFTER 1000 HOURS AT TEMPERATURE
STRENGTH AT TEMPERATURE 1000 HOUR EXPOSURE
STRESS TO PRODUCE .5% TOTAL DEFORMATION IN 1000 HOURS
STRENGTH AT TEMPERATURE ½ HOUR EXPOSURE
STRESS TO PRODU .5% TOTAL DEFORMA IN 100 HOURS
MODULUS OF ELASTICITY ½ HOUR EXPOSURE
26
24
22
20
18
16
14
12
10
8
6
4
2
100
200
300
400
500
600
EQUILIBRIUM TEMPERATURE (DEG F)
REF: THE DOW CHEMICAL COMPANY

FIG. 12

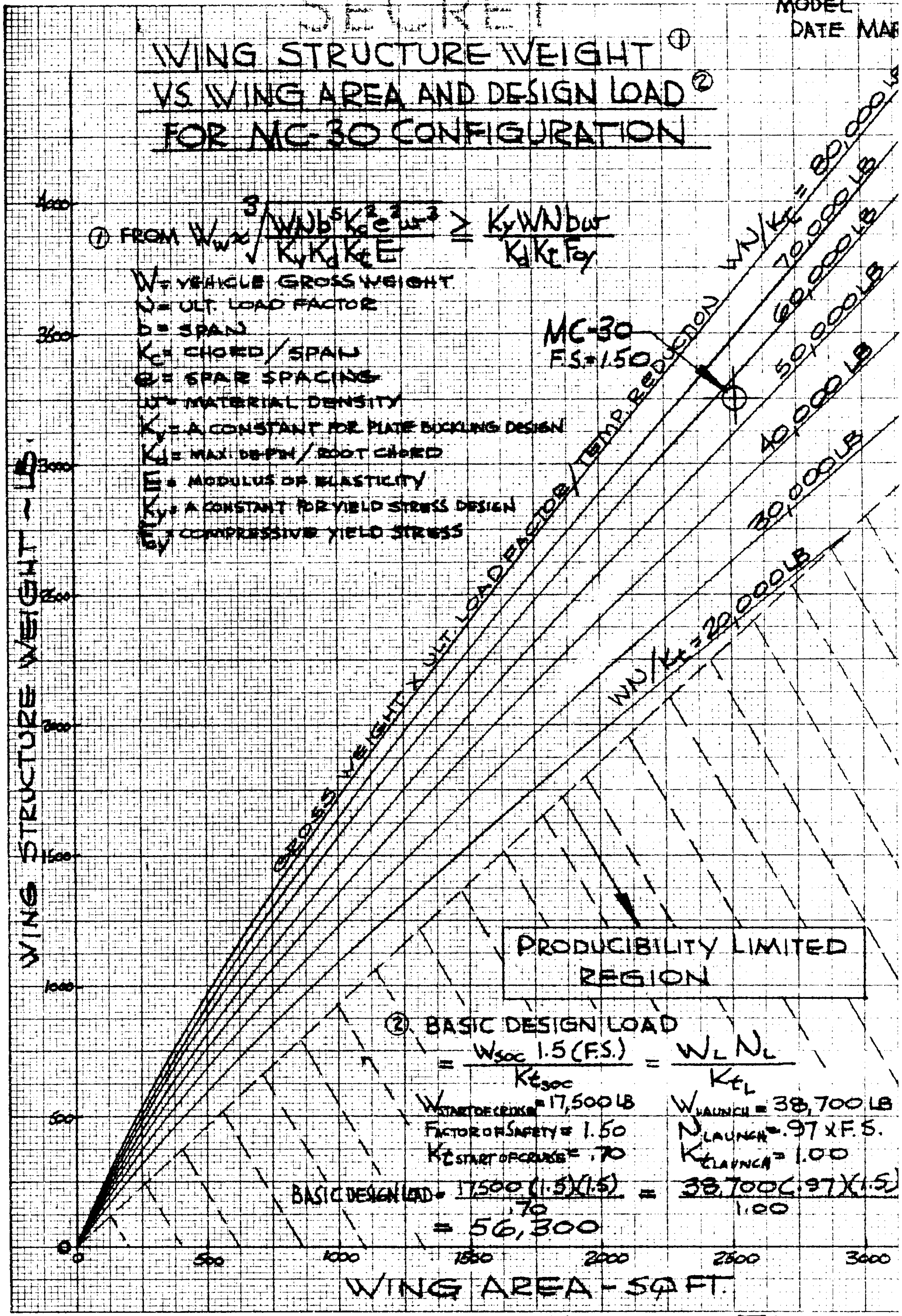
WING STRUCTURE WEIGHT ①
VS WING AREA AND DESIGN LOAD ②
FOR MC-30 CONFIGURATION
① FROM $W_W \propto \sqrt[3]{\frac{WNb^5K_c^2e^2\omega^3}{K_yK_dK_tE}} \geq \frac{K_yWNb\omega}{K_dK_tF_{cy}}$
W = VEHICLE GROSS WEIGHT
N = ULT. LOAD FACTOR
b = SPAN
K_c = CHORD / SPAN
e = SPAR SPACING
ω = MATERIAL DENSITY
K_y = A CONSTANT FOR PLATE BUCKLING DESIGN
K_d = MAX. DEPTH / ROOT CHORD
E = MODULUS OF ELASTICITY
K_y = A CONSTANT FOR YIELD STRESS DESIGN
F_{cy} = COMPRESSIVE YIELD STRESS
MC-30
F.S. = 1.50
WN/Kt = 80,000 LB
70,000 LB
60,000 LB
50,000 LB
40,000 LB
30,000 LB
WN/Kt = 20,000 LB
GROSS WEIGHT × ULT. LOAD FACTOR / TEMP. REDUCTION
PRODUCIBILITY LIMITED REGION
② BASIC DESIGN LOAD
$= \frac{W_{soc}\ 1.5\,(F.S.)}{Kt_{soc}} = \frac{W_L N_L}{Kt_L}$
$W_{START\ OF\ CRUISE}$ = 17,500 LB
FACTOR OF SAFETY = 1.50
$Kt_{START\ OF\ CRUISE}$ = .70
W_{LAUNCH} = 38,700 LB
N_{LAUNCH} = .97 × F.S.
Kt_{LAUNCH} = 1.00
BASIC DESIGN LOAD = $\frac{17500\,(1.5)(1.5)}{.70}$ = $\frac{38,700\,(.97)(1.5)}{1.00}$
= 56,300
WING STRUCTURE WEIGHT ~ LB
4000
3500
3000
2500
2000
1500
1000
500
0
0
500
1000
1500
2000
2500
3000
WING AREA - SQ FT.

FIG. 13

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5. All geometry varies linearly.

6. Same material used throughout airframe.

7. Optimum spar spacing is 6 inches for 4% thick wing with isotropically stiffened panels with a panel stiffness ratio of 6.

8. Producibility minimums are:

Webs	=	.016 inches
Panels	=	.010 inches subpanel thickness

9. All fastening is by welding, normal riveting and blind riveting.

10. Manufacturing cost toleration per unit of weight saving is relatively high.

11. Leading edge component is replacable and has a design life of 100 hours.

Figure 14 is an illustration of wing structure unit weight versus wing area and design load. Several presently operational delta wing aircraft are included for comparison of both the large loading difference and the resulting unit weight disparity. (Example Design Loading:* F-106 = 448#/Ft^2, MC-30 = 22#/Ft^2, Unit Weight: F-106 = 7.1#/Ft^2, MC-30 = 1.3#/Ft^2). It should be noted that the MC-30 vehicle and design criteria are quite radical when compared to existing aircraft; so much so that direct comparison is not valid.

* Design Loading = $\frac{Wn}{K_t S}$

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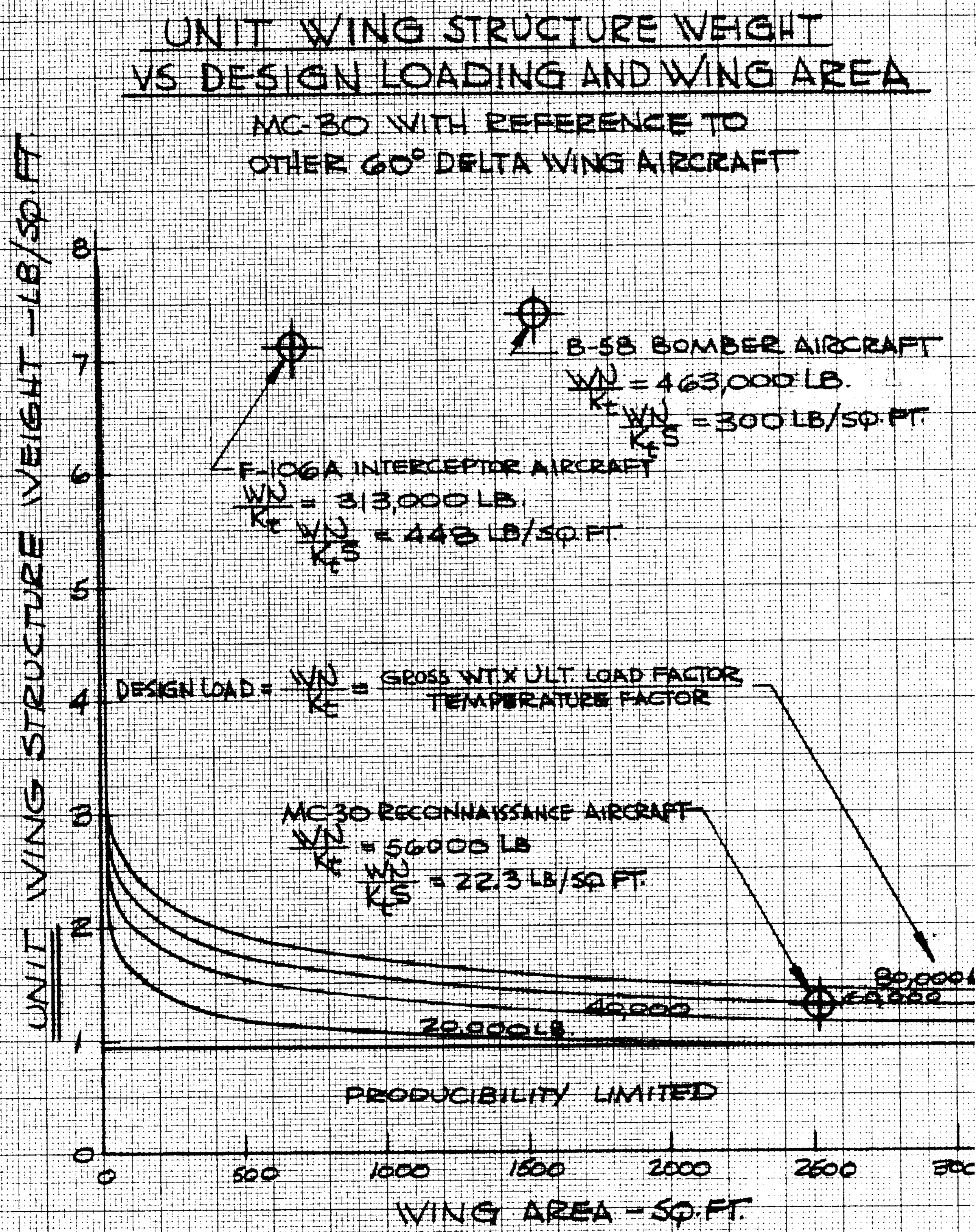
UNIT WING STRUCTURE WEIGHT
VS DESIGN LOADING AND WING AREA
MC-30 WITH REFERENCE TO
OTHER 60° DELTA WING AIRCRAFT
UNIT WING STRUCTURE WEIGHT - LB/SQ FT
B-58 BOMBER AIRCRAFT
WN/Kt = 463,000 LB.
WN/KtS = 300 LB/SQ FT
F-106A INTERCEPTOR AIRCRAFT
WN/Kt = 313,000 LB.
WN/KtS = 448 LB/SQ FT
DESIGN LOAD = WN/Kt = GROSS WT X ULT. LOAD FACTOR / TEMPERATURE FACTOR
MC-30 RECONNAISSANCE AIRCRAFT
WN/Kt = 56000 LB
WN/KtS = 22.3 LB/SQ FT
80,000
60,000
40,000
20,000 LB.
PRODUCIBILITY LIMITED
0
1
2
3
4
5
6
7
8
0
500
1000
1500
2000
2500
3000
WING AREA - SQ FT

FIG. 14

SECTION III

TEST MODEL WING

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SECTION III

TEST MODEL WING

The design of a test model wing using the same type of all metal construction proposed for the MC-30 vehicle (Reference Section II of this report) is shown in this section. This model is laid out to the same general dimensions as the test specimen being built by Goodyear Aircraft Corporation of pressure stabilized non-metallic construction (Reference Goodyear Drawing 481AB027).

A 60° delta wing in planform, the model has a 12 foot root chord, which gives a wing area of 83.10 square feet. A symmetrical "airfoil" section with a maximum thickness of 4% located at the two-thirds chord line is used. This "airfoil" section does not aerodynamically represent the one proposed for the MC-30 vehicle; the maximum ordinate on the MC-30 wing is located farther forward, and the chord plane is warped. It was picked for two reasons: First, to compare structurally to the Goodyear model the maximum section depth had to be located at the centroid of the wing planform. Second, to simplify construction, a double arc section cut normal to the maximum thickness line was chosen. The symmetrical feature would reduce tooling costs since skin panels could be made in two pairs, one right and one left hand. Leading and trailing edges are of .050 inch diameter with the exception of the nose section. In planform, the nose section as well as the wingtips are trimmed to a 6 inch radius (again following the Goodyear layout). At the nose this results in a thick leading edge which is simply rounded off to reduce complication. See Figure 15 for illustration of this wing shape.

A mounting fitting is located at the point of maximum thickness to allow the metal wing model to fit into the same test set up as for the inflated non-metallic model. A central beam simulates the center section structure of the vehicle. All other components of the model wing are made to full scale dimensions and follow the same construction methods as for the MC-30 vehicle.

Construction is of the multiple spar type with integrally stiffened skin panels. The skin panels have a grid pattern of one inch spacing produced by the chemical etching process. Spars and ribs are made up of thin corrugated webs with cap channels, attached by spotwelding,

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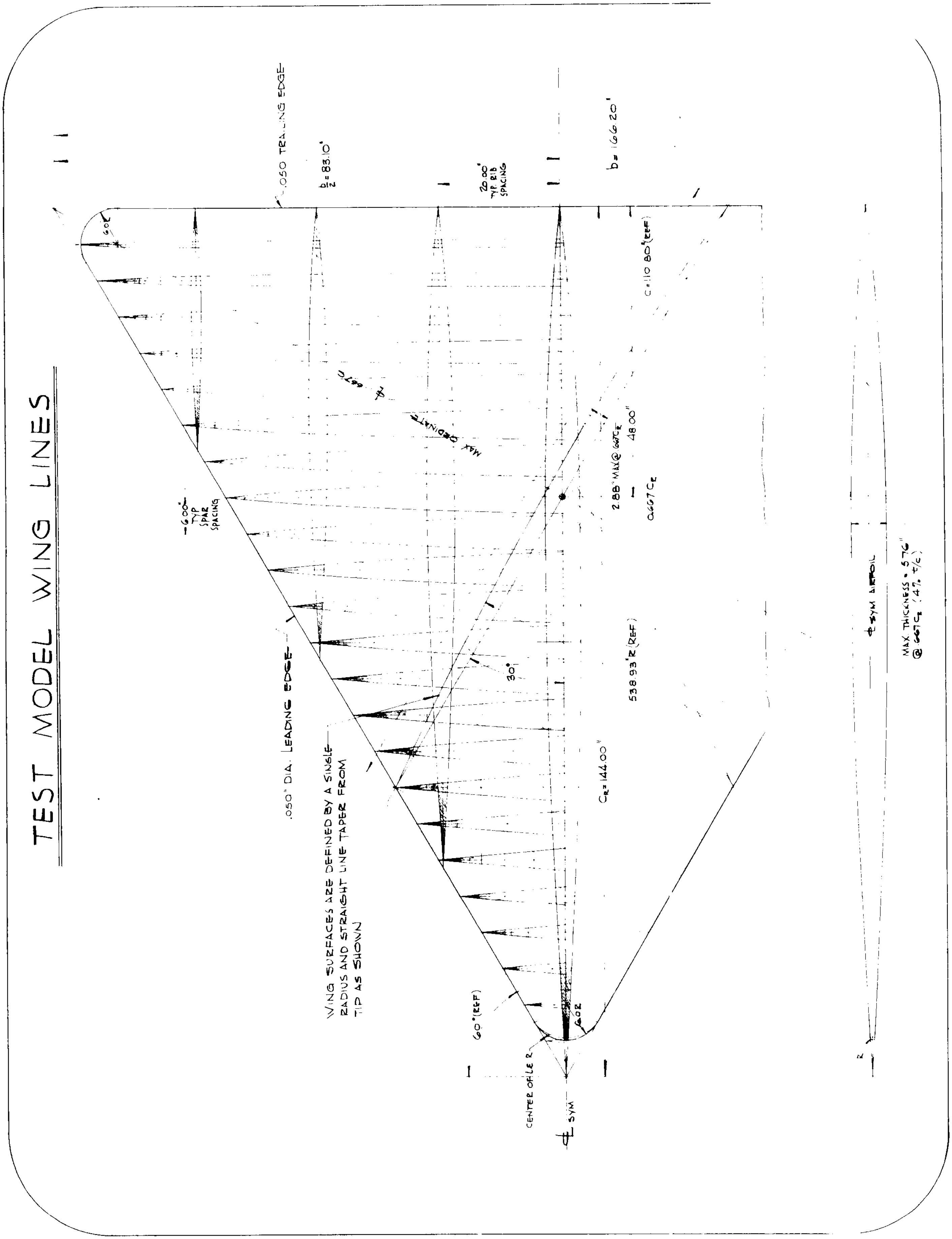
TEST MODEL WING LINES
.050 TRAILING EDGE
b/2 = 83.10
20.00 TYP. RIB SPACING
b = 166.20
c = 110.80 (REF)
MAX ORDINATE
6.00 TYP SPAR SPACING
2.88 MAX @ .667 C_R
48.00
.667 C_R
30°
538.93 R (REF)
.050 DIA. LEADING EDGE
C_R = 144.00
WING SURFACES ARE DEFINED BY A SINGLE RADIUS AND STRAIGHT LINE TAPER FROM TIP AS SHOWN
60° (REF)
CENTER OF LE R
℄ SYM
℄ SYM AIRFOIL
MAX THICKNESS = 5.76 (@ .667 C_R) (4% t/c)

FIG. 15

forming the rails. The spars are spaced at 6 inch intervals, the ribs located 20 inches apart. Skin panels have a thickened pad to match all spar and rib rails (part of the chemical milling process) and are attached by countersunk rivets. Blind explosive rivets are used for the closing side. Leading and trailing edges, as well as wingtips and nose sections, are full sandwich structures with plain skins and a rigid polyurethane core foamed in place through the closing channels. These components then attach to the basic structure as replaceable parts, although they are riveted at this splice.

All metal used in the model wing is magnesium except the mounting fitting and the fasteners. Sheet and plate parts are HK31A-H24, parts machined from bar stock in lieu of extrusions, are ZK60A-T5.

Figure 16 is the general structural arrangement and Figure 17 includes all typical details of construction.

The mounting fitting attachment and center beam have been nominally designed for a test loading of 20 lbs./sq. ft. applied uniformly to the model wing with a single reaction at the mounting fitting, assumed applied with the model at 305° F.

Table 3 is a comparative summary of the calculated model wing weights and the estimated wing weight of the MC-30 vehicle. It should be noted that the 83 sq. ft. model wing has significantly higher proportions of perimeter structure and minimum depths which yield unit weights greater than a 2,000 sq. ft. surface.

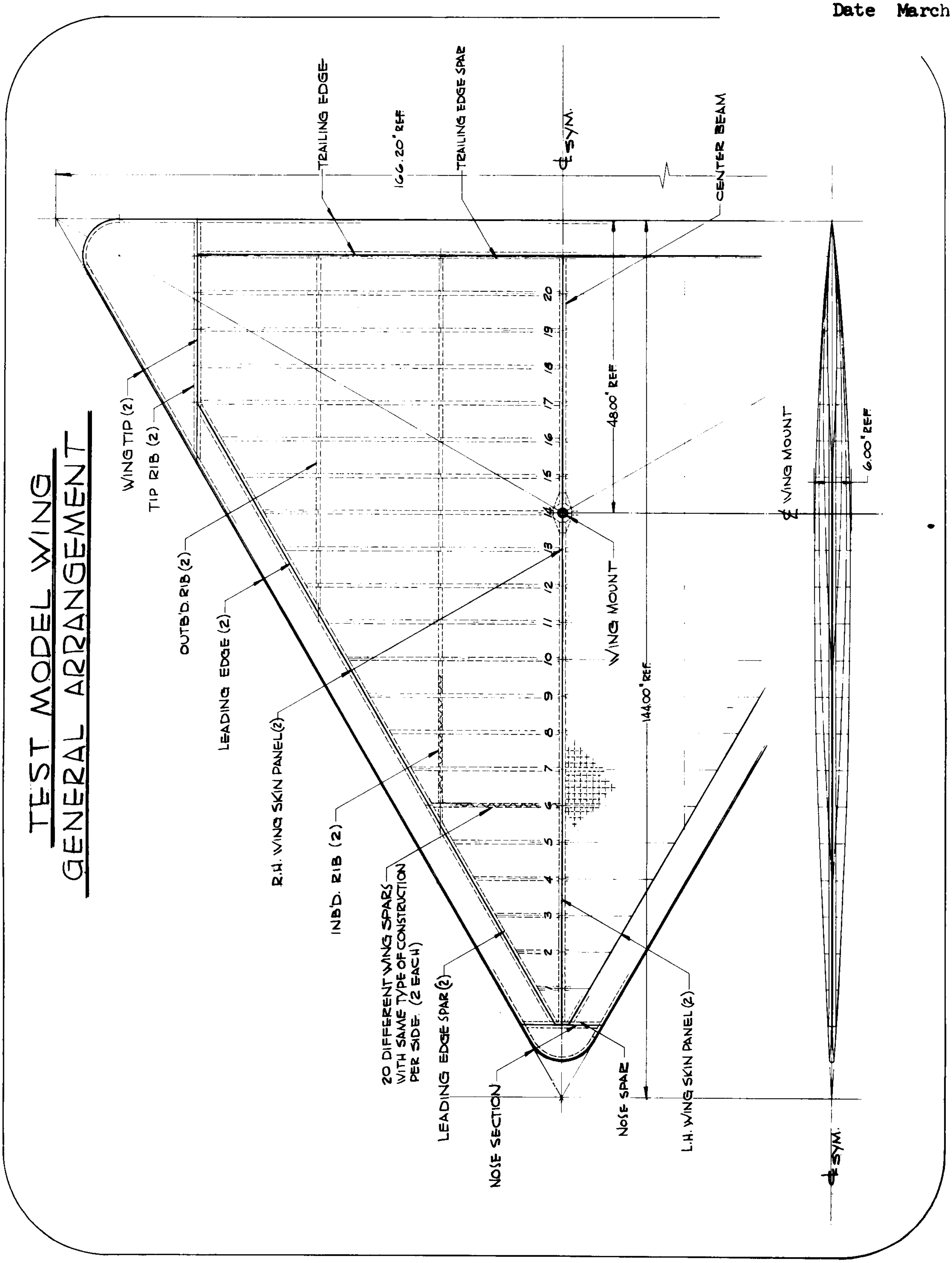
TEST MODEL WING
GENERAL ARRANGEMENT
TRAILING EDGE
166.20" REF
TRAILING EDGE SPAR
℄ SYM.
CENTER BEAM
WING TIP (2)
TIP RIB (2)
OUTB'D. RIB (2)
LEADING EDGE (2)
R.H. WING SKIN PANEL (2)
INB'D. RIB (2)
20 DIFFERENT WING SPARS WITH SAME TYPE OF CONSTRUCTION PER SIDE. (2 EACH)
LEADING EDGE SPAR (2)
NOSE SECTION
NOSE SPAR
L.H. WING SKIN PANEL (2)
WING MOUNT
48.00" REF
144.00" REF
℄ WING MOUNT
6.00" REF
℄ SYM.

FIG. 16

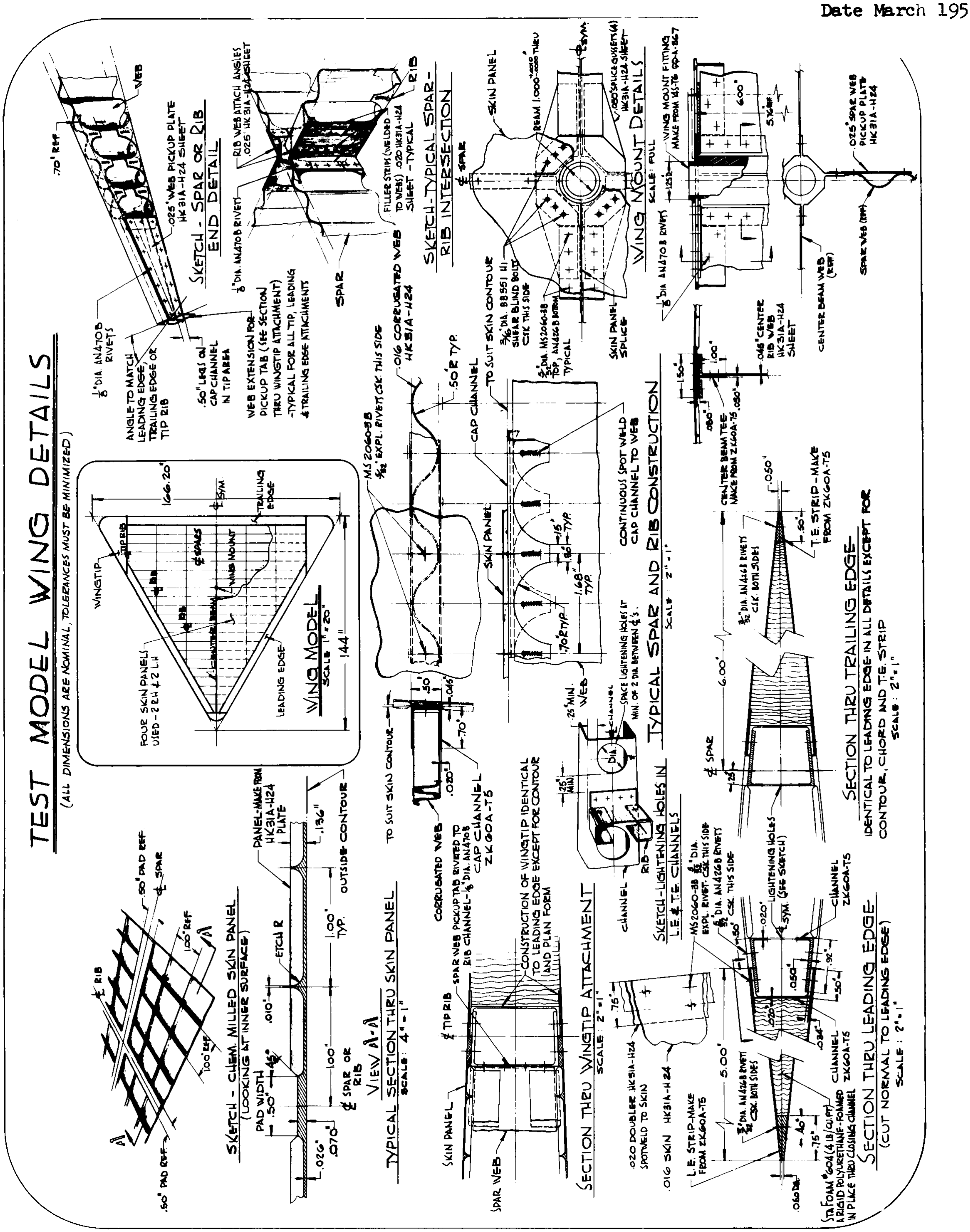
TEST MODEL WING DETAILS
(ALL DIMENSIONS ARE NOMINAL, TOLERANCES MUST BE MINIMIZED)
WING MODEL
SCALE 1"=20"
166.20"
144"
WINGTIP
TIP RIB
LEADING EDGE
TRAILING EDGE
FOUR SKIN PANELS USED - 2 R.H. & 2 L.H.
SKETCH - CHEM. MILLED SKIN PANEL
(LOOKING AT INNER SURFACE)
VIEW A-A
TYPICAL SECTION THRU SKIN PANEL
SCALE: 4" = 1"
OUTSIDE CONTOUR
PANEL-MAKE FROM HK31A-H24 PLATE
ETCH R
SECTION THRU WINGTIP ATTACHMENT
SCALE: 2" = 1"
CONSTRUCTION OF WINGTIP IDENTICAL TO LEADING EDGE EXCEPT FOR CONTOUR AND PLAN FORM
SKETCH - LIGHTENING HOLES IN L.E. & T.E. CHANNELS
TYPICAL SPAR AND RIB CONSTRUCTION
SCALE: 2" = 1"
CONTINUOUS SPOT WELD CAP CHANNEL TO WEB
SECTION THRU LEADING EDGE
(CUT NORMAL TO LEADING EDGE)
SCALE: 2" = 1"
SECTION THRU TRAILING EDGE
IDENTICAL TO LEADING EDGE IN ALL DETAILS EXCEPT FOR CONTOUR, CHORD AND T.E. STRIP
SCALE: 2" = 1"
SKETCH - SPAR OR RIB END DETAIL
SKETCH - TYPICAL SPAR-RIB INTERSECTION
WING MOUNT DETAILS
SCALE: FULL
CENTER BEAM TEE MAKE FROM ZK60A-T5
T.E. STRIP - MAKE FROM ZK60A-T5
L.E. STRIP - MAKE FROM ZK60A-T5

FIG. 17

COMPARISON ~ WING WEIGHTS ~ TEST MODEL AND MC-30 VEHICLE

COMPONENTS	WEIGHT LB.		AREA SQ. FT.		UNIT WT. LB/SQ. FT.		% OF TOTAL WEIGHT		% OF TOTAL AREA	
	MODEL	MC-30	MODEL	MC-30	MODEL	MC-30	MODEL	MC-30	MODEL	MC-30
BASIC STRUCTURE										
SKINS	49.9	1694					44.4	42.8		
SPARS	15.0						13.3			
RIBS	3.6	1040					3.2	40.4		
CENTER BEAMS	3.9						3.5			
TOTAL	72.4	2734	61.5	2391.3	1.18	1.15	64.4	83.2	74.1	94.8
PERIMETER STRUCTURE										
NOSE	1.7	2	0.5	0.5	3.40	3.40	1.5	.05	.6	—
TIPS	9.2	10	7.2	7.2	1.28	1.28	8.2	.30	8.7	.29
LEADING EDGE	17.6	168	8.6	83.0	2.03	2.03	15.7	5.10	10.3	3.30
TRAILING EDGE	9.3	68	5.2	38.0	1.79	1.79	8.3	2.05	6.3	1.51
TOTAL	37.8	248	21.5	128.7	1.76	1.93	33.7	7.5	25.9	5.1
TEST MOUNT	2.1	—					1.9			
CONTROLS & MISCELL.	—	308						9.3		
COMPLETE WING	112.3	3290	83.0	2520	1.35	1.31	100	100	100	100

TABLE 3

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SUMMARY

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SUMMARY

I. Launch Study

Tactical and development problems restrict launching method considerations to the aircraft and rocket boost combination. The mission requirements of the vehicle also demand unique launching methods to yield reasonable vehicle size and structure weights. The primary (by aircraft) launch stage must provide gust load protection for the vehicle. The secondary launch will consist of two rocket boost stages. The initial rocket boost stage must be of the zero lift launch type to avoid gust load problems, using gimballing rocket motors for attitude control. The final rocket boost stage is in a region where aerodynamic trajectory control can be used. This launch method was examined only sufficiently to establish its feasibility.

II. All Metal Airframe Configuration

An all metal configuration, MC-30, was designed using the identical requirements of the MC-10 non-metallic vehicle. The MC-30 is an all magnesium airframe of chemically etched integrally stiffened panels on a multi-spar substructure of corrugated webs, welded and riveted. The metal airframe is heavier than the non-metallic airframe. The major portion of this weight difference is due to a difference in factor of safety (1.15 non rigid, 1.50 for "rigid" metal), and the growth factor to maintain a given wing loading.

		MC-10	MC-30
Weight at Start of Cruise	Lb.	13,800	17,500
Booster Weight	Lb.	16,725	21,200
Weight at Air Launch	Lb.	30,525	38,700
Wing Area	Sq. Ft.	1,985	2,520
Wing Span	Ft.	67.71	76.29
Average Cruise Altitude	Ft.	131,400	131,400

The metal airframe is structurally more desirable than the non-metallic, non rigid vehicle. The metal, rigid vehicle offers no

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material and construction development problems of consequence, permits easier manufacture and maintenance, higher structural reliability, greater growth or modification potential and probably lower cost. A small reduction in operating altitude with a consequent increase in wing loading would tend to reduce the weight disadvantage.

III. Model Wing

A model wing design of MC-30 metal construction was made to compare with the Goodyear Aircraft Company non-metallic wing. The details worked out for the model are typical of the design of the full scale MC-30 vehicle.

Study of the possible uses of such a model design show it as being useful for detail design study, fabrication study and detail weight estimation to verify the configuration. Also, comparative testing of such models of different types of construction would yield useful engineering data. A theoretical analysis and load deflection determination was considered impractical within the limits of this present program.

IV. System Requirements

The system requirements used are within the present capability of the aircraft industry. The use of non-metallic materials would demand more development in areas of presently limited activity, while the metal airframe makes only moderate demands of existing materials and methods.

Preliminary studies indicate that the 132,000 foot cruise altitude is the primary factor responsible for the unconventional systems and airframe proposed. In ZP-267 "Low Altitude Hazel Studies", a preliminary study is made of a configuration for a cruise altitude of approximately 90,000 ft. and a 4,000 nautical miles range in which it is shown that more conventional systems and airframe construction can be used.

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REFERENCES

ZP-252 Summary (Brochure of charts and text)

ZP-253 Aircraft Design

ZA-282 Aerodynamics

ZJ-026 Propulsion, Structure Heating, and Pressurization

ZP-267 Low Altitude Hazel Studies (Brochure)

Goodyear Aircraft Corporation Drawing No. 481AS027

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APPENDIX

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APPENDIX A

EFFECTS OF LOAD FACTOR AND MATERIALS ON WEIGHTS OF AN MC-10 TYPE VEHICLE

SUMMARY

The effect of substituting rigid metal construction for the non-metallic, inflatable MC-10 is to increase start-of-cruise weight from 13,800 lbs. to 17,500 lbs. for a range of 3,200 nautical miles. This is shown in Figure 18. For either construction the design load factors assumed during launch and boost result from gusts only.

The effect of assuming a two-g pullup at launch, together with gust loads, is to increase structural weight of either the metal or inflatable vehicle such that the MC-10 cruise range cannot be attained within a reasonable size limit. The increased design load factor causes a much greater range loss for the inflatable vehicle than for the metal vehicle. These effects are also shown in Figure 18.

INTRODUCTION

A brief study was made to estimate the effects of design load factor and/or construction materials on the start-of-cruise weight of an MC-10 type vehicle.

DISCUSSION

In studying the effects of design load factor and/or construction materials, it was assumed that the basic MC-10 parameters were held constant, i.e.,

1. Altitude at start of cruise = 125,000 ft.
2. Cruise at constant Mach number = 3.0
3. Wing loading at start of cruise = 6.95 lbs./sq. ft.

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4. Lift-to-drag ratios unchanged by increasing size.

5. Specific fuel consumption unchanged by increasing size.

6. Cruise mass ratio required for 3,200 nautical miles range unchanged (start cruise to empty weight is constant).

7. Total range of 3,200 nautical miles required.

These assumptions are valid except that lift-to-drag ratio will actually increase slightly with vehicle size. The L/D increase would result from relatively smaller pilots canopy, relatively thinner wing leading edges and increase in Reynolds number.

The calculation procedure used was to assume a start-of-cruise weight, and for this weight compute the required wing, tail, and engine sizes and weights. Fixed weights were added, and then, fuel and tankage to equal the assumed total. The resulting mass ratio was then used to compute the range. This procedure was repeated until the relationship between weight and range were clearly shown.

The effect of replacing the inflatable, non-metallic structure of the MC-10 with rigid magnesium compression design structure is to increase the start-of-cruise weight from 13,800 lbs. to 17,500 lbs. The range calculation results are shown in Figure 18.

The MC-10 was designed for maneuvers at cruise weight only. When loaded to launch weight the MC-10 structure is capable of withstanding a 0.97 g load factor. This load factor is considered to result entirely from gust loadings and the allowable maneuvering load factor is zero.

The effect of increasing the MC-10 launch design load factor by two g's, with non-metallic inflatable structure, is to decrease the maximum possible mass ratio. Thus this vehicle can never carry enough fuel to attain the MC-10 range of 3,200 nautical miles. This result is shown in Figure 18 where the range is always less than 3,200 nautical miles for any assumed weight and is shown decreasing rapidly with increasing size. Maximum attainable range is approximately 1,400 nautical miles.

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The effect of increasing the MC-10 launch design load factor by two g's, together with a change to rigid magnesium compression structure, is again to decrease the maximum possible mass ratio. This result is also shown in Figure 18 where the range is increasing with increasing weight but the total weight becomes excessive without attaining the required 3,200 nautical miles. The range of the metal vehicle, while less than the 3,200 nautical miles range of the basic MC-10, is much greater than for the non-rigid vehicle when each is designed to 2 g's plus gust loads at launch.

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REPORT NO. ZP-266
MODEL
DATE MARCH 1959

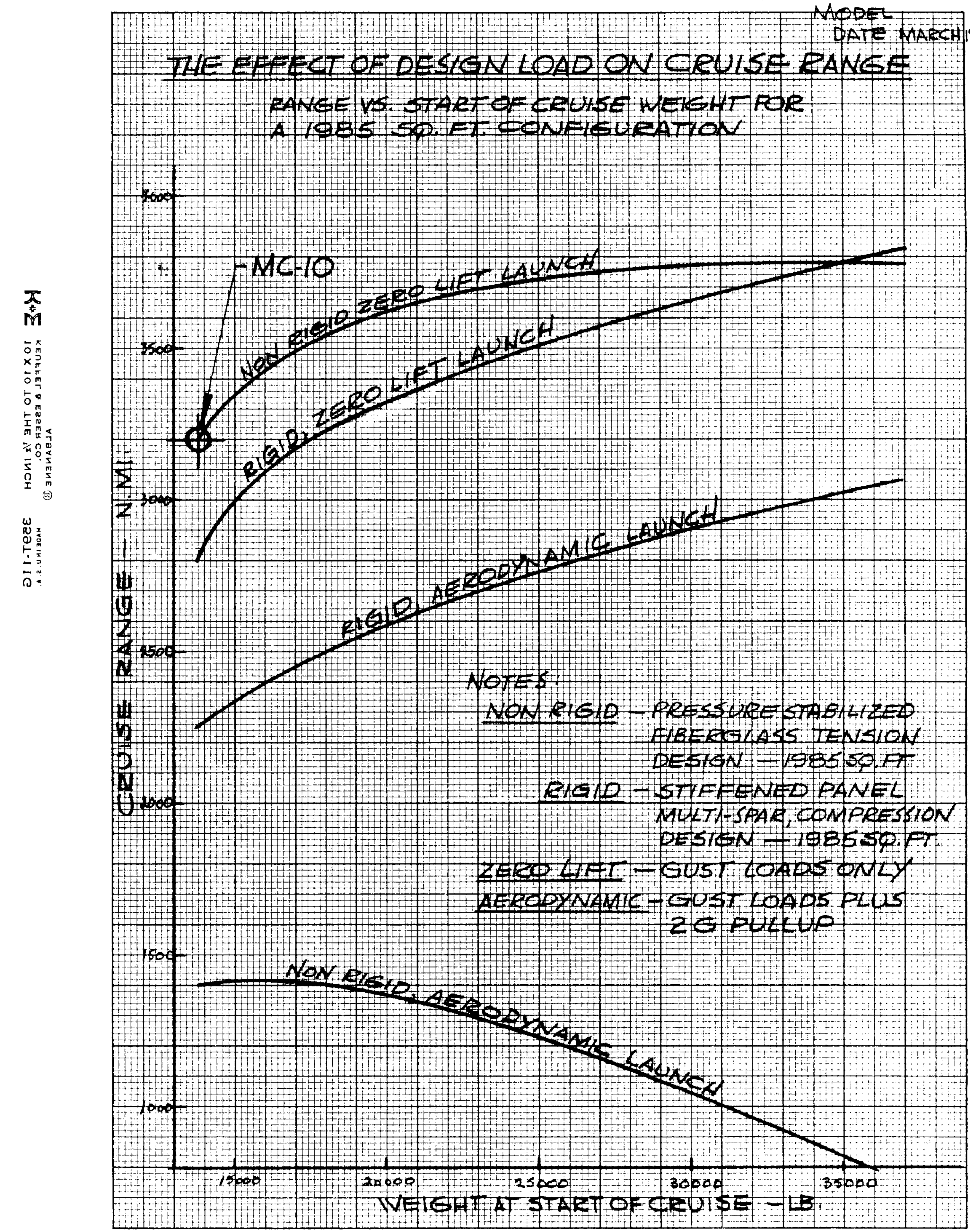

FIG. 18